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The Northern Forest Research Centre (NoFRC) of the Canadian Forestry Service is responsible for fulfilling the federal role in forestry research, regional development, and technology transfer in Alberta, Saskatchewan, Manitoba, and the Northwest Territories. The main objective of the center is to conduct research in support of improved forest management for the economic, social, and environmental benefit of all Canadians. Since 1982 the center has also assumed responsibility for the development and implementation of federal-provincial forestry agreements and employment stimulation programs in the forestry sector.

One of six regional research centers, two national forestry institutes, and a headquarters unit, NoFRC is located in Edmonton, Alberta, and has district offices in Prince Albert, Saskatchewan, and Winnipeg, Manitoba. Until joining Agriculture Canada in 1984 under a Minister of State for Forestry, the Canadian Forestry Service was part of Environment Canada.

Cover photo:

A free-burning active crown fire in the boreal forest region of central Alberta (photo by M.E. Alexander).

PROCEEDINGS OF THE INTERMOUNTAIN FIRE COUNCIL 1983 FIRE MANAGEMENT WORKSHOP

D.E. Dubé, compiler[1]

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NORTHERN FOREST RESEARCH CENTRE
CANADIAN FORESTRY SERVICE
1985

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ABSTRACT

The annual meeting was held October 25–27, 1983, in Banff, Alberta. Various fire management topics were covered, including the economic impact of forest fires, the political implications, initial-attack initiatives in Alberta, operational research approaches, management of large fires in the Northwest Territories, British Columbia, and Ontario, and suppression options.

RESUME

La réunion annuelle a eu lieu du 25 au 27 octobre 1983 à Banff, Alberta. Divers sujets se rapportant à la lutte contre les incendies y ont été traités: les répercussions économiques des incendies de forêt, les conséquences politiques, les projets d'attaque initiale en Alberta, les méthodes de recherche opérationnelle, la lutte contre les gros incendies dans les Territoires du Nord-Ouest, en Colombie-Britannique et en Ontario, et les divers moyens de suppression.

FOREWORD

The 1983 annual meeting of the Intermountain Fire Council marked the second time that the council has met in Canada; the inaugural conference was held in Edmonton, Alberta, in 1978[1]. Over 200 delegates from the United States and Canada attended the two and one-half day workshop held in Banff, Alberta, on October 25-27, 1983.

The Intermountain Fire Council's 1983 fire management workshop consisted of three half-day sessions devoted to the theme *Suppression Options and Alternatives*, preceded by a keynote address. The first session, concerning "Socio-economic and political considerations", involved three papers. The second, entitled "Strategy and tactics", covered both initial attack and escaped fires and had six presentations. The final session featured four "Additional perspectives" related to the workshop's theme, the highlight of which was N.P. Cheney's overview of Australian wildland fire management practices and problems. Two concurrent field trips were held during the afternoon of the second day. A summary of the workshop was presented on the morning of the final day and was followed by a report on the Canadian Interagency Forest Fire Centre by C.A. Jeffrey and the council's business meeting. Biographical sketches of the invited speakers plus their co-authors and session moderators are contained on Pages 90-93.

A very special thanks is due to H.W. Gray of the Alberta Forest Service (AFS), who along with D.E. Dubé served as program cochairman. In addition to the speakers, the following individuals and organizations made various contributions to the success of the workshop:

- A.D. Kiil, Regional Director, Northern Forest Research Centre, Canadian Forestry Service (CFS), and C.B. Smith, Director, AFS Forest Protection Branch, for their support of both the technical and social aspects of the workshop.
- D. Quintilio, Alberta Forest Technology School, and T. Van Nest, AFS, for their assistance with the program and numerous support functions.
- R.G. Krebill, C.S. McDonald, and A.J. MacAuley, who along with D.E. Dubé served as session moderators.
- R.G. Newstead, CFS, for his role in coordinating the numerous exhibitors and their displays.
- K. O'Shea, AFS, who organized and led the Kananaskis Country tour in the Bow-Crow Forest of southwestern Alberta.
- Parks Canada, in particular C.A. White for his help with many logistical details and in organizing and leading the Banff National Park tour.
- N.P. Cheney, who so capably gave the after-dinner address at the workshop banquet following the last minute cancellation of the scheduled speaker.
- G.B. Turtle and J.K. Samoil, CFS, for their very fine efforts in editing the workshop preceedings.
- M.E. Alexander, CFS, for his assistance in the initial planning of the workshop theme and program content.
- Canadian Committee on Forest Fire Management for their endorsement of the workshop as a national forum for presentations on fire management in Canada.

Finally, the Alberta and Northwest Territories components of the Intermountain Fire Council would like to express their sincerest appreciation and gratitude to the late Richard J. Sandman for originally initiating formal Canadian involvement in the council.

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[1] Quintilio, D., compiler. 1979. Proceedings of the International Fire Management Workshop. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-215.

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KEYNOTE ADDRESS

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Let me begin by saying how pleased I am to be here and how honored I am to be asked to present the keynote address for the opening of the Intermountain Fire Council 1983 Fire Management Workshop. The organizers and coordinators of this gathering should be congratulated for arranging these proceedings and for sticking with their program even during this period of economic recession when support and travel I am sure were at a premium.

The Intermountain Fire Council meetings have in the past, and, it appears, will in the future, provide one of the few forums that are available to a wide spectrum of fire management people. The Northwest Fire Council and Northeast Fire Supervisors are other associations that come to mind as having provided yeoman service in the development of associations and the sharing of knowledge.

My message this morning will be basically one of sticking with the task in spite of what sometimes appear to be insurmountable odds. I believe many of us are here today because we are just not prepared to accept defeat and collectively believe we have attempted to tackle almost every imaginable circumstance. Through the sharing of our collective experiences we will all become better managers.

I can think of probably 100 examples of how persistence won but I would like to use the example of the development and signing of the Canada-U.S. Reciprocal Forest Fire Fighting Resources agreement as one we should all be quite proud of. I was not involved in the development of the concept; however, I am quite aware of a number of circumstances that I believe will illustrate how persistence has paid off. I personally first became involved in the development of the Canada-U.S. agreement in March of 1975, when I was requested as Vice-Chairman of the Canadian Committee of Forest Fire Control to attend a National Wildfire Coordinating Group meeting in Orlando, Florida. Our American colleague, Bob Bjornson, and I remained one additional day, under duress, in Orlando and drafted the first draft of what is now the Canada-U.S. Reciprocal Forest Fire Fighting Arrangement.

Upon the completion of his term as Chairman of the Canadian Committee the following year, Len Sleman of Ontario closed his address to the gathering with a statement of regret that the Canada-U.S. agreement had not been completed as planned. Suffice to say that I personally held the chairmanship on two occasions following that address and was also not able to report the completion of the task. I believe that credit must go to Don Merrill and his associates in the Department of External Affairs and the State Department, for the agreement was signed on May 7, 1982.

I have personally had a number of inquiries about the development of the agreement and how we managed to have it completed in such a short period of time. It was indicated that some bureaucrats actually complete whole careers without ever finalizing a single international agreement such as the Canada-U.S. Reciprocal Forest Fire Fighting Arrangement. The value of this agreement came into play during the 1982 and 1983 fire seasons when equipment was moved across the international boundary without any difficulty. As a Canadian, it certainly did my heart good to be able to assist this year in the transfer of commercial air tankers and equipment from Ontario to assist our good neighbors to the south.

The meeting this week is truly an international gathering and has indeed been enhanced by the participation of our Australian friends. I would suggest to those of you in the operational field who conduct competitions on an annual basis relative to the performance of your crews that you might reconsider making them universal. I must warn you, however, that recent happenings have indicated that Australians are indeed in the habit of collecting silverware, as indicated by their performance in the Americas' Cup competition. Ingenuity, cooperation, persistence, innovation, new technology, and above all, dedication to a task indeed played important parts in improving their skills and must indeed become a part of fire management programs so that we can improve our everyday skills.

The theme of this week's fire management workshop is "suppression options and alternatives". Through the presentations and discussions to come I know that we will address each of the traits I have outlined, and let me predict that many of you here will long remember this meeting, meet new people, make new friends, and as a result expand the community of fire management. Buzz words are the in thing in fire control today and I believe that by Thursday you will all agree that this was truly a technology transfer session.

Although I have not been a regular participant at the Intermountain Fire Council meetings, it was indeed a Fire Council meeting at Boise, Idaho, in 1968 that made me aware of the Fire Science program at the University of Washington. I subsequently attended and graduated from that program. Since that time I have been involved in the direct suppression role as well as in the development of programs on a provincial, national, and for that matter an international basis, as alluded to in my reference to the Canada-U.S. Reciprocal Forest Fire Fighting Arrangement and participation in the F.M.S.G.

Let me say that as a keynote speaker it would be appropriate to provide a little philosophy on the subject and some background relative to my career in forest fire management. One never considers himself to be a philosopher; however, I am probably as opinionated as any individual in this room and can probably spout as many one-liners as any of you. It is, however, necessary for me to provide some background information that is really classified and should not be divulged to the general public, and especially to the political arena.

I was going to begin my presentation this morning with a wake, as you are undoubtedly aware that the original Smokey the Bear has passed away, and unfortunately this was the only basis for many of our fire management programs. Such an approach would make light of the importance of this gathering as well as the role of Smokey the Bear, and let me assure you that the discussions this week will have far-reaching implications. If we are not successful in our endeavors I can only feel sorry for the generations of Canadians that will follow us.

A few foresters, let me emphasize a very few foresters, have come to realize that the state of forestry in Canada is in disarray. This subject is the center of discussion of all CCREM ministers' and deputy ministers' meetings, federal-provincial cost-sharing meetings, the meetings of industry associations, the Canadian Institute of Forestry, and a host of other meetings too numerous to detail.

All of us in this room are very young relative to the time frame of a forest, and I must admit that it is only in the past few years that I have become aware of the fact that we were indeed at a critical point relative to the supply of raw material for our sawmills and pulp and paper mills. Persons are cutting, burning, wasting, alienating, and destroying our heritage. The reason I use the term "person" is that our political masters have been keeping themselves busy with important items like gender, bilingualism, the constitution, medicare, energy policy, nuclear disarmament, and a host of other irrelevant topics when the resource base of our largest industry is being depleted and lost.

We have all heard the numbers indicating the importance of forestry and that it is larger than agriculture, mining, and manufacturing combined. It did my heart good at Regina this past fall at a Drought Committee meeting to tell agriologists that the forest industry contributes $23.4 billion to our gross national product, while cereal grain crops produce only $4.6 billion.

The value of our forest resource will continue to be eroded as a result of the fact that we have overcut and alienated forest land for other uses, tried to farm much of it, reforested very little of it, and provided little or no protection from insects and disease, and at best our protection from fires could be considered acceptable. Our fire history records have shown that we have had some absolutely disastrous decades, including the one we are currently in. Some of the decades that come to mind include the 1880s, when in 1885 Louis Riel burned much of southern Manitoba and parts of Saskatchewan, and in 1889, when it was reported that fires burned from Alaska to Mexico; the great dustbowls of the 1930s; and the 1960s, when in 1961 and 1967 disastrous fire years occurred. In 1967 the country spent a total of $17 million fighting forest fires and the powers that be at the time indicated that steps had to be taken to ensure that such expenditures never again occurred. In 1982 the nation spent something in excess of $230 million fighting forest fires, and a critic might suggest that it is not only the fires that are out of control.

An appropriate question might be to ask why we are in the present situation. It is my opinion that the reason is that we just do not possess enough knowledge and authority to address the problem before us. This is indeed the reason we are here this week: to improve our knowledge and skills, and to go away with a better understanding of the task before us. The papers to be presented over the next three days are appropriate both in timing and content.

I alluded to the importance of forestry to Canada and the socioeconomic benefits derived from the resource. It was the single most important agent responsible for much of the development in this country and continues to be so important to our everyday standard of living.

We as a fire community in Canada have attempted to develop a damage appraisal or value-at-risk system. Let me assure you that if we do not get our act together and develop an appropriate system, we will fall even further behind in not only selling our programs but in protecting the ones we already have from budget cuts.

Political considerations affect us on a daily basis as the role of the politician is felt in our everyday operations and sometimes in our daily work decisions. This fact should not be considered as a hindrance or an interference, but should be used to our advantage to improve the delivery of our programs. Let me give you an example of how the involvement of politicians resulted in the acquisition by Manitoba of the first CL-215. Let me begin by asking how many in this room have ever heard of a Saunders aircraft and how it might result in the acquisition by forest protection staff of a piece of very expensive equipment to improve a program unrelated in every way to the Saunders aircraft story.

The Saunders aircraft was an 18-place flying culvert built with a stretched Bristol Heron air frame and the addition of PT6 turbine engines. Suffice it to say that few are still flying; however, the saving of the production of that aircraft played a key role in the acquisition of the CL-215 for Manitoba.

The Manitoba premier at that time had a desire to continue the manufacture of the aircraft, and when he became aware of our request for a CL-215 he eventually got around to asking Canadair to provide offset work to Saunders to keep them in business. Canadair was not prepared to take over or assist Saunders but it did agree to assist another corporation, C.A.E. Aircraft Limited, to continue its operation in Winnipeg. C.A.E. resulted from the moving of Air Canada Maintenance from Winnipeg to Montreal during the 1960s.

The happy conclusion to the scenario is that from 1977 to 1983 Canadair has provided the Manitoba airspace industry with some $27 million of offset work and the Forest Protection Section of Manitoba is now in possession of three Canadair CL-215s.

Don't let me coerce you into believing that the program was developed on a step-by-step process and that everyone was knowledgeable of all the happenings at any given time. Let me assure you, however, that persistence paid off and almost always does as an individual minister or cabinet becomes more knowledgeable about the program, or else is subsequently changed. The ear of a new minister or cabinet is usually quite reachable. The purchase of 29 CL-215s under the Cooperative Supply Agreement took probably as many turns and twists as did my experience with the purchase of the first CL-215 for Manitoba. The time frame involved was certainly quite short, and although I must go on record as saying that I do not support all of the activities that took place with the development of the Cooperative Supply Agreement program, it has indeed turned out to be a resounding success. How many of you, including some who have purchased C1-215s, have ever heard of the "SCRAP" program? It is almost unbelievable that an economic recession could result in the acquisition of many millions of dollars worth of equipment for the protection of our most valuable natural resource.

I for one am looking forward to the presentations and discussions that will take place this week and I will have another opportunity later in the program to report to you on the development and management of the Canadian Interagency Forest Fire Centre.

Before I get to my final summary, let me give you a little criticism of fire management people that I believe applies to probably myself as much or more than anyone else in this room. That criticism is that fire management cannot be all things to all people. We have had a history of responding positively to all situations brought before us, whether it be a flood or other natural catastrophe, a search and rescue operation, or the development of communications networks and the establishment of administrative organizations.

There are other people who are receiving salaries and have responsibilities and I believe it is incumbent upon us to ask questions of others as many ask of us. I believe that approach as taken by our friends to the south with the development and now the implementation of the NIIMS system has much merit, and I believe such a concept in a smaller form should be encouraged in Canada.

Let me begin my summary by saying that forest protection is still a motherhood issue and many of you are held in the highest esteem by not only the public but the electorate as well. Let me remind you, however, that that is not enough and that we must do much more in order to develop and sell our programs. A very relevant fact is that politicians now want some of the opportunity to be in the limelight, and if we play our cards right we can do much to enhance and sell our programs through them to the governments involved.

We certainly do not have all the answers and research must be promoted on a national and international basis to improve our level of knowledge; through gatherings such as this we can disseminate such information to an operational level. No single one of us has the ability or the resources to do all the necessary work alone, and national and international cooperation must become a part of our everyday thinking if we are to be successful in our endeavors.

The time to improve the level of fire management is now, and I believe that most governments, regardless of their development strategies, have protection at the top of their requirement list.

Last but not least it is a fact that we will all benefit, not just the members of the fire management community but the world as a whole will benefit, from the exploitation through the protection of our natural resource. All of us as members of the fire management community must look to the challenge before us.

Thank you and have an enjoyable, productive week.

ESTIMATING FIRE-INDUCED NET VALUE CHANGE IN RESOURCE OUTPUTS

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ABSTRACT

Estimates of the fire-induced changes in the net value of resource outputs are needed in analyzing the economic efficiency of fire management program options. The appropriate measure of economic efficiency is the minimization of program cost plus net value change in resource outputs and structures. In computing net value change, the analyst must identify the resource affected, define the management objectives, determine the area from which resource output changes are measured, and carefully specify the parameters describing the fire situation. Net value change estimation capability can be provided to users in several ways. One is in the form of general-purpose computer software. Another way is to calculate the changes for generic fire situations and record the results in look-up tables. Illustrative net value change estimates for fire situations in the northern Rocky Mountains of the United States are presented as an example of this look-up table approach.

INTRODUCTION

In the last decade, concern about the economic efficiency of fire management programs and the need for integration of these programs into the entire land management process has risen dramatically. An early indication of this concern was the request in 1975 by the U.S. Office of Management and Budget for information about the economic efficiency of the USDA Forest Service's fire management program (U.S. Department of Agriculture 1977). Even earlier, Leopold et al. (1963) had addressed the "natural" role of fire in the management of the U.S. Department of the Interior, National Park Service's fire program. Subsequent changes in the fire management policy of the two resource agencies responded to these concerns. The Forest Service's 1978 policy revision requires fire management programs to be cost-effective and fully integrated with the land management program (U.S. Department of Agriculture 1981). In 1968 the National Park Service revised its fire policy to permit fire to play a more "natural" role (Kilgore 1983).

The Forest Service's policy change was followed by several studies of the economic efficiency of fire management alternatives (Schweitzer et al. 1982; U.S. Department of Agriculture 1980, 1982b). Each study was an important step in the continuing evolution toward a complete and low-cost method to analyze the efficiency, risk, and resource output impact of fire program alternatives.

Economic efficiency in fire programs is measured by the minimization of fire program cost plus the fire-induced net change in the value of the resource outputs (Simard 1976; Gorte and Gorte 1979; Mills 1979; Mills and Bratten 1982). This cost plus net value change (C + NVC) criterion is a transformation of the present net worth maximization criterion typically applied in investment analysis; a transformation is necessary because of our inability to estimate the resource impact of having no fire management program at all.

Although efficiency can be improved in the short run by reducing the cost of one program through increased expenditures of another — for example, by decreasing suppression costs through increased fuel treatment or initial attack expenditures — all costs must be justified in the long run by their impact on the value of resource outputs. Estimating those net value changes continues to be one of the most difficult analytical problems in fully implementing the revised fire policies that require economically efficient programs.

Earlier nationwide studies show that fire effects on timber and structures dominate the net value change, expressed in dollars. Timber contributed 60% and structures 19% of all net value changes in a study of 41 national forests (U.S. Department of Agriculture 1980). The relative importance of net value change contribution by resource category, though, varies by geographic area. For example, timber dominated the net value change on the Willamette National Forest in Oregon and structural effects dominated the net value change on the San Bernardino National Forest in southern California (Schweitzer et al. 1982).

The estimated dollar-valued net value change has been less than the cost of presuppression and suppression activities in some study areas, such as on the Tonto National Forest in Arizona (Schweitzer et al. 1982). This difference signifies one of two possibilities: the nondollar-valued effects that were excluded from the study were important in the program decision, or the scope of the analysis was too restrictive and should have tested alternative suppression programs as well as alternative initial-attack programs. The latter possibility raises the question of whether large initial attack and suppression costs should be borne if the expected net value change under the simulated budget levels is really so small.

The net value change estimates in economic efficiency studies are generally restricted to measures of the dollar-valued effects of fire. Because some of the resources affected by fire cannot be valued in dollars, the net value change does not combine into a single index all fire impacts that should be considered in a fire management decision. Despite that limitation, the dollar-valued net value change is still an important ingredient in fire management analyses.

This paper describes the major computational characteristics of a procedure for estimating fire-induced changes in resource output, and demonstrates the procedure's application through sample calculations of net value change in the northern Rocky Mountains of the United States.

COMPUTATION OF NET VALUE CHANGE

Net value change is the fire-induced change in the present net value of resource outputs. This relationship can be generally described by the formula

$$NVC = PNV1 - PNV2$$

where: NVC = net value change
PNV1 = present net value "without" fire
PNV2 = present net value "with" fire.

In the simple case where the fire does not influence per-unit value and only affects output in the year of the fire, net value change can be simply described by the formula

$$NVC = V(Q1 - Q2)$$

where: V = per-unit value of the fire-affected output
Q1 = "without fire" output level on the fire-impacted area
Q2 = "with fire" output on the fire-impacted area.

The fire-induced change in output is the difference between the "with" and the "without" fire output levels and not between "with" and "without" the fire program, as is usually done in economic evaluations. The "without fire" bench mark is used because the resource output change that would occur from the "without program" bench mark cannot be feasibly estimated for the fire program. We do not know how damaging or beneficial fires would be in the total absence of fire management.

If fire affects the per-unit value of resource outputs, then a separate value must be estimated for both output levels by the formula

$$NVC = (V1)(Q1) - (V2)(Q2)$$

where: V1 = per-unit value "without" fire
V2 = per-unit value "with" fire.

This situation might occur if a timber stand were scheduled for harvest in the year of the fire and the fire induced not only a volume loss but also a stumpage price reduction from the "without-fire" green price to the "with-fire" salvage price.

If the fire also influences the timing of the outputs in other years, then all net revenues for the "with" and "without" fire situations must be discounted to the year of the fire. If in addition the fire affects management costs, the "with" and "without" fire costs must be included in the calculation. In short, anything that affects the magnitude or timing of resource outputs, per-unit output values, or management costs must be incorporated in the net value change computation. Anything that is unchanged by the fire can be ignored.

Net value change is the present value of future changes in output, per-unit values, and management costs. It is not an estimate of the compounded cost of establishing the resource affected by the fire. For example, if a timber stand is burned, the net value change is determined from the future output of the fire-impacted area, not the present value of past stand establishment costs. Those past stand establishment costs are economically sunk and cannot be retrieved. Even replacement cost should only be used as a proxy for resource values when they are a reasonable estimate of present value. Replacement cost of burned structures is an example where replacement cost is used if market transaction data are not available.

Although fairly simple in concept, net value change computations have been handled quite differently by various authors. Examples of the various aspects of the computation include the management objective where output change is measured, and completeness of the specification of future outputs, costs, and values.

IDENTIFYING THE RESOURCES FOR VALUATION

Identification of the resources included in the net value change calculation should be based on the ease of assigning dollar values and the closeness of the resources included in the calculation to the resources physically affected by the fire. Resources should only be included if reasonable dollar values can be derived, either by direct assignment from market transaction information or by an opportunity cost calculation of the benefits foregone to gain that output. The difficulty of assigning dollar units is the reason net value changes are seldom calculated for archeological resources and air quality deterioration.

The resources in the calculation should be those closest in the production path to the resources affected by the fire, and at the same time be those directly associated with human use (Althaus and Mills 1982). Therefore, stumpage should be valued in the timber calculation rather than lumber because lumber has substantial value added due to manufacturing that should not be attributed to fire's impact. The impact of fire on wildlife and sport fishing, on the other hand, should be measured in terms of changes in the recreational usage of those outputs, rather than by changes in the habitat or population of the wildlife and fish species. The fire-induced change in habitat and population output is difficult to measure, and the outputs are difficult to value directly.

DEFINING MANAGEMENT OBJECTIVES

The objectives of management must be clearly understood and reflected in the time stream of resource outputs from the affected area. Objectives should be identified in a two-step process. The first step is to determine whether there would have been any usable resource output in the affected area in the absence of the fire. If there would have been output, the second step is to determine the impact that management has on the timing and magnitude of the output.

Wilderness areas provide an example of the first step. "Trees" may burn in a wilderness fire, but since the trees were never going to be harvested in the first place, no "timber" was lost and therefore no timber net value change should be calculated.

Timber management objective differences found on national forest lands, as reflected in the regime of management actions, provide an example of the second step. Timber stands managed primarily for timber production, for example, typically have shorter rotations and more-frequent commercial thinning entries than stands where nontimber objectives are more important. The corresponding changes in the timing and magnitude of timber outputs, as well as the impact of those changes on unit values, in turn affect the net value change. Management regime differences between national forests and most private lands have even greater impact on the estimated net value change. Similar management differences must be considered in calculating net value changes in range, water yield, sediment, recreation, wildlife, fishing, and structures.

The net result of these management objective influences is that two fires of similar size and intensity, burning in similar vegetation conditions, can have very different net value changes. Since the management objective affects the components of the net value change calculation, it also affects the net value change estimate itself.

DETERMINING AREAS OF MEASUREMENT

Somewhat related to the issue of management objective is determination of the area from which the fire effects on resource outputs are measured. At least two options are available. The first is to measure only direct physical and biological effects on the fire site, such as timber harvest changes on the burned site, and direct off-site effects, such as sedimentation and flooding that occur downstream from the fire site. The second option is to measure the change in output that occurs on the entire management unit or market area where the fire site is found. This second option permits the manager or the market forces to substitute unburned resources that would not otherwise have been utilized in the absence of the fire for the burned resource that is no longer available.

Authors differ about which of the options should be selected. Lindenmuth et al. (1951), Marty and Barney (1981), Schweitzer et al. (1982), and the U.S. Department of Agriculture (1982a) all follow the first option and propose measurement of the fire site only. Mactavish (1966), McLean (1970), Bakker (1975), and Crosby (1977) all recognize the issue of substituting unburned for burned resources but then formulate the calculation for the fire site only. Simard (1976), Brown and Boster (1978), Van Wagner (1979, 1983), and Knapp (1982) all follow and incorporate the substitution of unburned for burned timber rather than restricting output changes to the fire site only. Several of these studies also demonstrate that the decision to include or exclude substitution has considerable impact on the timber net value change in some circumstances, especially if the harvest is constrained to below financially optimum levels.

This substitution issue closely parallels the timber management issue of whether the impact of inventory-enhancing actions, such as tree planting, should be measured by changes in the harvest from the entire management unit or from the planted site only. The relative impact on the financial return of the management action when substitution is included or excluded in timber management analyses is the reverse of its impact in fire analyses (Bell et al. 1975). Including substitution in analyses of tree-planting investments tends to increase an investment's financial return over a "treated site only" analysis, while including the substitution assumption in a fire analysis tends to decrease the financial return to fire management investments.

Some of the resolution to this debate lies in the eventual use of the net value change estimates, uses which vary from long-term planning to postfire damage appraisals. Many of the policy and management program constraints that are fixed in the postfire appraisal setting are not fixed in long-term planning. The net value estimate in long-term planning should reflect as closely as possible the fire's impact on the inherent productivity of the forest resource, rather than productivity confounded by what are sometimes ephemeral constraints. The function of planning is to help set reasonable constraints that in turn provide guidance in subsequent implementation of resource programs. At the very least, the opportunity cost of the constraints interjected into the planning setting should be estimated.

The substitution issue is relevant for resources other than timber too, such as range and recreation. The management decision to move livestock from the burned area to an underutilized unburned area is very similar to timber substitution. The movement of recreationists from the burned site to another area, along with the commensurate increases in travel and congestion costs, is an example of substitution caused by market forces rather than management decisions. In fact, it is probably impossible to disentangle the substitution effect from the fire site effect when recreational net value change estimates are derived from contingent valuation methods[1].

We propose that the net value changes for long-term planning should include the fire's impact on output from the fire site and the direct physical impact off-site rather than output effects that reflect management-induced substitution (Althaus and Mills 1982). Constraints that confound the fire's effect on the inherent resource productivity with such effects as those of inventory liquidation policies should not influence the net value change estimate (Teeguarden 1973).

COMPLETENESS OF THE NET VALUE CHANGE COMPUTATION

How complete should resource output, cost, and per-unit value impacts be reflected in the computation of net value change? Mactavish (1966), for example, forwarded a rather complete formulation of the timber net value change calculation. He incorporated fire impacts on the timing of final harvests, price differences between green and fire-salvaged timber, stand establishment cost differences due to seed source removal by the fire, forest type conversions linked to fire disturbance, and potential insect and disease losses. Other authors have proposed much simpler formulations.

Two alternative forms of the timber net value change calculation were studied to determine how varying degrees of computational completeness would affect the estimates (Mills and Flowers 1983). The objective should be to use the simplest, and therefore least costly, formulation that produces sufficiently accurate answers. We found that a simple formulation produced consistently higher timber net value change estimates than did the more complete formulation for a sample of 24 cases in the northern Rocky Mountains. Since the net value change differential was often substantial, we concluded that a fairly complete model formulation, which more fully reflects actual management actions, is essential. Similar questions of computational completeness must be addressed through model sensitivity analysis for the other resources.

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[1] Vaux, H.J.; Gardner, P.D.; Mills, T.J. 1983. The impact of fire on the value of recreation. U.S. Dep. Agric., For. Serv., Pac. Southwest For. Range Exp. Stn., Berkeley, Calif. Unpublished report.

SPECIFYING FIRE SITUATION PARAMETERS

Fire situation parameters required in long-term planning applications should include descriptors for fire severity, fire site, and management regime. Fire size and percent tree mortality or fire line intensity are adequate fire severity proxies for most resource categories.

The relevant fire site and management regime parameters vary by resource and geographic region. For example, vegetative cover type, site productivity, slope class, stand size, and access are appropriate fire site descriptors in the timber net value change calculation because each of these affects some of the data input. Cover type affects timber yields, stumpage prices, and management costs. Site productivity affects yields and is a link to different management regimes. Slope class affects the logging system used on public lands and through that the stumpage price. Stand size at time of fire affects the salvage decision because salvage feasibility is linked to tree diameter and stand volume. Access is also an important determinant of salvage feasibility. Percent mortality, access, and aspect, on the other hand, are the only important fire and fire site parameters needed to estimate water yield and sediment production changes due to fire.

The management regime identifier for the timber net value change calculation may include four classes: (a) "intense public" management—timber production is the major objective within the multiple-use management setting; (b) "modified public" management—timber production occurs but is tempered by a stronger multiresource objective; (c) "intense private" management—timber is managed to maximize financial returns; and (d) "passive private"—only stand establishment treatments and final harvest are present. The management regime characterization for the range calculations might instead be reflected by levels of grazing utilization in a similar classification.

Once the parameters of the fire situations are defined, the appropriate accuracy of the data needed in the net value change computation must be determined. The effort put into the data collection and analysis process should be commensurate with the sensitivity of the net value change answers to cost-saving analysis simplifications and the accuracy needed in the particular application of the net value change estimates. This can be accomplished most effectively by testing, in a few case studies, the sensitivity of the net value change estimates to changes in the input for outputs, costs, and per-unit values.

In a sensitivity analysis of net value change to input data errors for 24 timber cases, we found that the greatest data collection effort should be concentrated on the stumpage price estimates and first rotation timber yield data (Mills and Flowers 1983). The sensitivity results also helped in assessing the confidence that could be placed in the net value change estimates, since the confidence in the input data is comparable with the sensitivity of the net value change estimate to input data errors.

DELIVERING NET VALUE CHANGE ESTIMATES

Net value change estimates are sensitive to the computation model form, the parameters used to define the fire situation, and the accuracy of input data. It is not readily apparent, therefore, how best to transfer knowledge about the net value change calculation from the analyst to the eventual user of the estimates. At least two options exist. One option is to design general-purpose computer software that is flexible enough to accept a wide range of resource, management objective, and parameter set combinations. Users would then determine the most appropriate analysis structure and data set for their use and design much of the analysis themselves. The software would primarily ease the computational load. Software of this kind was developed for calculating the financial return of silvicultural investments (Goforth and Mills 1975).

A second option is to precalculate the net value changes for a number of generic fire situations and record the results in look-up tables. The users could then match the actual fire situation they face with the generic situation and extract the net value change estimate from the table. The look-up table approach has been used for net value changes in the northern Rocky Mountains of the United States for the recreation resource[2] and for the range resource[3]. The look-up table approach is also planned for timber net value changes[4] and water net value changes[5] in the same region.

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[2] Flowers, P.J.; Vaux, H.J., Jr.; Gardner, P.D.; Mills, T.J. 1983. Fire-caused net change in the northern Rocky Mountain recreation resource. U.S. Dep. Agric., For. Serv., Pac. Southwest For. Range Exp. Stn., Berkeley, Calif. Unpublished report.

[3] Peterson, D.L.; Flowers, P.J. 1983. Estimating fire-caused changes in production and value of northern Rocky Mountain rangelands. U.S. Dep. Agric., For. Serv., Pac. Southwest For. Range Exp. Stn., Berkeley, Calif. Unpublished report.

Because of the complexity of the net value change calculation for some resources, the difficulty of collecting adequate input data, and the similarity of individual fire situations between administrative units, we propose that net value change look-up tables be developed for use in long-term planning. This option has significant analysis efficiency and accuracy advantages. Achievement of these advantages requires close communication between the analyst and the eventual user when the fire situations are first defined. That close initial linkage with the user will lower data collection costs and enhance acceptance of the final results.

Several net value change estimates for fire situations in the northern Rocky Mountains were calculated according to the analysis structure described earlier. Two case study estimates were calculated for each of the following resources: timber, range, water, and recreation (Table 1). The relative magnitude of the estimates is similar to earlier studies in that the timber estimates are much larger than those for the other resources, on the side of both net detrimental (positive sign) and net beneficial (negative sign) effects. The recreation and range impacts, on the other hand, are small. The water yield net value change is generally much lower than the timber estimate and is consistently beneficial. The variation in these estimates between different sets of fire situation parameters shows the importance of a well-specified computational method and fire situation parameter set. An expanded set of timber estimates were then prepared in the look-up table format (Table 2).

CONCLUSIONS

Probably one of the most controversial aspects of the net value change computation method is whether the substitution of unburned for burned resources should be reflected in the computation. We suggest that substitution should not be included in estimates intended for long-term planning applications because it clouds the underlying resource productivity impact of the fire with the sometimes ephemeral management constraints.

Whichever computational form is adopted, there are several options for delivery of estimates to users in a practical form. We have proposed that look-up tables be produced for direct access by the user, especially for applications to long-term planning or escaped fire situation analyses. That delivery method promises to ensure the greatest accuracy and computational efficiency, even though it incurs some errors due to extrapolation from the stylized fire situations in the tables to actual fire situations.

Although we suggested how the net value change computation should be structured—particularly for long-term planning applications—this in no way implies that no further work is needed in this area. Further work is required concerning data accuracy and the definition of the fire situation. Additional effort is also needed on several aspects of the conceptual form and context of the computation, such as how to best handle the substitution issue. We hope this paper stimulates such endeavors.

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[4] Mills, T.J.; Flowers, P.J. 1983. Wildlife-induced change in the present net value of timber stands in the northren Rocky Mountains. Unpublished report.

[5] Potts, D.; Zuuring, H.; Peterson, D.L. 1983 Watershed modeling for fire management planning in the northern Rocky Mountains. Unpublished report.

Table 1. Two cases (A, B) of fire-induced net value changes (NVC) in timber range, water, and recreation resources, northern Rocky Mountains of the United States[a]

Parameters	Timber A	Timber B	Range A	Range B	Water A	Water B	Recreation A	Recreation B
Fire site								
Timber type	DF	PP	DF	PP	—	—	—	—
Size class	Pole	Sawlog	Pole	Sawlog	—	—	—	—
Site class	Mod.	low	—	—	—	—	—	—
Aspect	—	—	—	—	N	S	—	—
Slope (%)	<40	<40	<40	<40	—	—	—	—
Access	Roaded	Roaded	—	—	Roaded	Roaded	—	—
Fire severity								
Stand mortality	60+	0–29	—	—	60+	0–29	60+	0–29
Fire size (acres)	0–10	100+	—	—	—	—	—	—
Season	—	—	Summer	—	—	—	—	—
Management regime								
Emphasis	Intense public	Modified public	Low intensity	High intensity	— —	— —	Low intensity	Low intensity
Net value change								
1978 ($/acre)	$1122	–$262	–$10	–$1	–$79	$0	$1	–$1

[a] Empty cells represent parameters that were determined or assumed to have little impact on variation in fire-induced NVC for that resource. DF = Douglas fir, PP = Ponderosa pine.

Table 2. Estimates of net value change in timber burned in the northern Rocky Mountains[a]

Timber type	Stand size (cu. ft./acre/yr.)	Site class	Tree mortality (%)	Fire size (acres)	Net value change 1978 (dollars/acre)
Douglas fir	Sawtimber	120+	30–59	100+	−376
Douglas fir	Pole timber	120+	60+	0–9	1385
Douglas fir	Seedling/sapling	120+	0–29	10–99	0
Ponderosa pine	Sawtimber	85–119	60+	0–9	661
Ponderosa pine	Pole timber	85–119	0–29	100+	498
Ponderosa pine	Seedling/sapling	85–119	60+	0–9	296
Fir-spruce	Sawtimber	50–84	60+	0–9	311
Fir-spruce	Pole timber	50–84	0–29	100+	311
Fir-spruce	Seedling/sapling	50–84	60+	10–99	266

[a] Fire sites are on slopes exceeding 40% and in roaded areas under intense public management.

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THE ECONOMIC IMPACT OF FOREST FIRE

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ABSTRACT

Three elements of a simple economic analysis of fire's impact on the forest industry are described. The first is a projection of timber supply and the reduction in annual allowable cut caused by fire. The second is a relationship between fire control expense and the resulting average annual burned area. The third is the value to be placed on a unit volume of wood as it is harvested. The concept focuses on the whole forest and its timber yield rather than on the burned area and its fire-killed timber. The principle that emerges could be called "maximized net return".

INTRODUCTION

It is now some five or six decades since the first efforts at measuring the economic impact of forest fire in North America, and a small but continuous flow of literature has continued to the present day. Yet after all these years of organized fire control, the subject is still not resolved to everyone's satisfaction. Furthermore, the pressure for a rational answer is rising steadily among the major forestry provinces of Canada.

It would be tempting to say outright that the reason for this apparent failure was a wrong turn taken at the start. But it would be presumptuous to dispose so easily of the "least cost-plus-loss" concept that has held the stage for all this time. Perhaps it is not the concept itself but rather how it has been interpreted that should be questioned. So far, the interpretation of loss has been "net-value-change on the burned area", with the consequent demand for rules to measure "values-at-risk" from hectare to hectare. This activity leads directly into economic problems of great complexity and still we do not have a satisfactory answer. Add to this the nagging doubt as to exactly who it is that sustains the loss, and just whose bank account is being depleted.

How can one measure the economic impact of fire and judge how much protection to give the forest? Let us step back a moment from economics, whose medium is dollars, and look at the forest instead, whose medium is wood. Let us also consider just the forest industry and the use it makes of the forest, setting aside other forest uses and benefits for the present.

What exactly is it that keeps the forest industry in business? It is, obviously, nothing less than an assured annual timber supply. Strictly speaking, what goes on in the standing forest is of second-order relevance as long as the timber supply is forthcoming every year. If so, then the real job of the fire control agency is to protect the forest's annual increment rather than the standing forest *per se*. This may seem a subtle distinction, but once the point is accepted the decks are cleared for a logical chain of analysis.

TIMBER SUPPLY AND THE AAC

The first step is to shift our focus away from the burned area and its fire-killed timber. The timber supply comes from the forest as a whole, and we must broaden our view to encompass it all. We must, in fact, delve into the mysteries of timber supply analysis. But in its natural state, most of the Canadian forest is cycled and renewed by random periodic fire and has been for ages. Should we not then apply the same cool logic to the effect of fire on timber supply as we give to the harvesting process itself? This means projecting the effect of future fire as well as simply tracking the results of current depletions.

At Petawawa we have designed a little model that projects the available timber supply in a forest affected by fire as well as logging (Van Wagner 1983). The operator is required to state the annual proportions of the whole forest area that will be logged and burned, plus the forest's yield curve and initial age class distribution. The model then runs by two simple rules: 1) fire strikes at random at any age, and 2) the stand of highest volume is always cut. A sample of the results we obtained, based on a yield curve like that of black spruce in western Quebec, appears in Figure 1.

It is clear that for any given proportion of area burned annually there exists an optimum harvested area that will yield the maximum sustainable annual allowable cut (AAC). A graph of these maxima (Fig. 2) constitutes a direct measure of the impact of fire on the maximum potential timber supply, providing the first essential information for an excursion into an economic analysis of the fire control effort.

BALANCING THE FIRE CONTROL EFFORT

The second step is to determine just how the average annual burned area depends on the amount of money expended on fire control. The form of this curve is of great interest and importance. Let us assume two things:

1) if there were no fire control at all, the annual burned area would no doubt be much larger but still finite; and
2) it is impossible to reduce the burned area to zero without the expenditure of infinite funds.

The limits of the curve are therefore defined, and its shape will look something like Figure 3. Of course some real data would be greatly desirable, but just as obviously these would be very hard to come by. We have at least one point, namely the current state of affairs, and we must do the best we can to estimate the rest. This curve is the second essential for an economic analysis.

The third step is to place a value on the wood harvest itself, and now for the first time we must truly explore the mysteries of economics. What is a cubic metre of wood actually worth? I can think of at least four viewpoints, and an economist can no doubt think of even more.

There is, first, the viewpoint of the accountant who collects stumpage. For example, for purposes of reporting fire losses the provinces currently place a weighted average of about $300 on a hectare of merchantable timber, about $3 per cubic metre of harvested wood. But then, what about the viewpoint of the woods manager who judges a lost cubic metre by what it costs delivered to the mill entrance? And what about the viewpoint of the sales manager who thinks in terms of the value of the finished product as it is loaded for shipment? Finally there is the social economist who views the whole economic scene with its values-added and multiplier effects. So, for example, we saw that in 1980 in Ontario, while the Ministry of Natural Resources rated its timber loss in mere tens of millions, the forest industries were proclaiming that billions of dollars had gone up in smoke. Such a spread of two orders of magnitude in loss estimate serves only to drive home more strongly the problem of what value to place on the timber supply for purposes of protection.

Nevertheless, whatever a cubic metre of harvested wood is actually worth, we have now identified the third and final ingredient of a basic economic analysis. Clearly, we must simply maximize the difference between harvest value and fire control expense. Multiplying the AAC by its value per cubic metre, the two quantities are graphed in dollars over annual area burned (Fig. 4). The ideal position, when the difference is optimum, occurs where the two curves have an equal slope.

MAXIMIZED NET RETURN

In all of this, we have not really discarded the concept of "least cost-plus-loss". It is just that the loss is now conceived as a reduction in timber supply rather than as the fire-killed timber on the burned area. As it turns out, loss conceived in this way actually seems higher, since the reduction in AAC will generally turn out to be greater than the volume of fire-killed timber. But the harder one looks, the more confused the very meaning of loss seems to be. Is it the value of the reduction in potential AAC? But this will be a true loss only if a market plus the industrial capacity exist for the entire potential AAC. Or is it the cost of the fire control operations? And does it include the cost of substitution when imminent harvest plans are interrupted by fire?

When the system is operating at its economic optimum, then the marginal cost of further reduction in burned area just equals the value of the corresponding increase in AAC. if loss were then defined as "economically available increased harvest", there would, in the optimum state, be no loss. With your permission I will leave the definition of loss in an unresolved state, and suggest that the simplest way out of the confusion is to rename the whole concept. Instead of "least cost-plus-loss", call it "maximized net return". The pieces of the puzzle then fall neatly into place.

For example, the way to improve the whole position would be through improvements in the effectiveness of fire control, either through better organization or improved working tools. Research will surely be important. The climate and weather with respect to fire and the essential flammability of the forest are always, it is agreed, beyond our control.

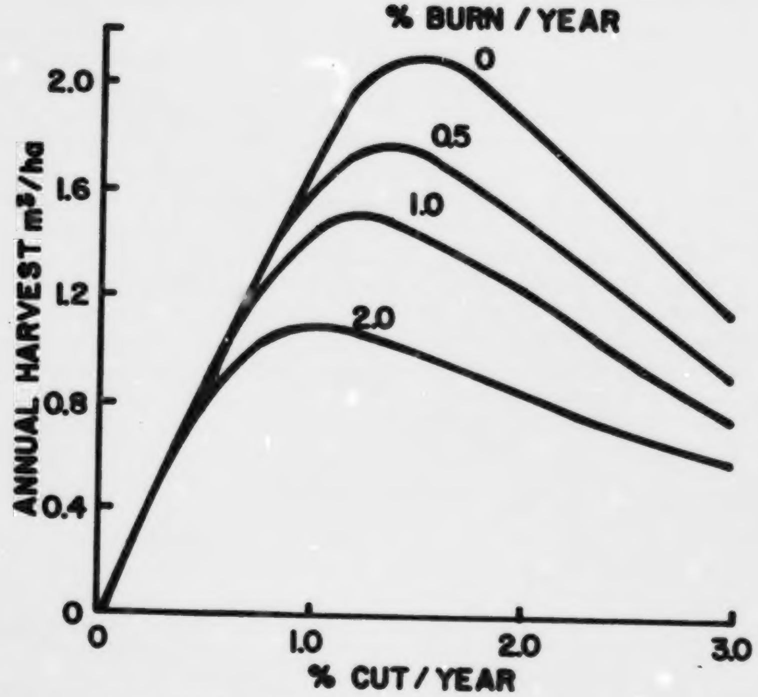

Figure 1. Curves of equilibrium annual harvest over percentage of area cut annually, for various levels of area burned.

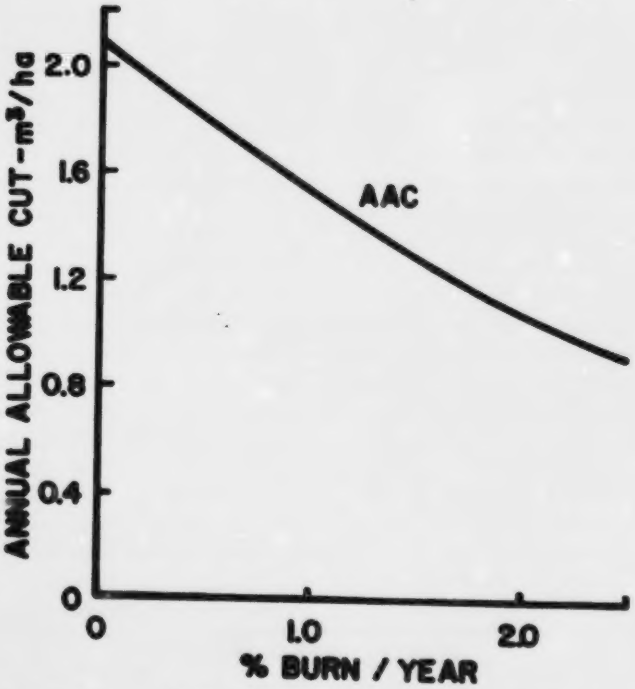

Figure 2. Annual allowable cut over percentage of area burned annually; the focus of the maxima of the curves of Fig. 1.

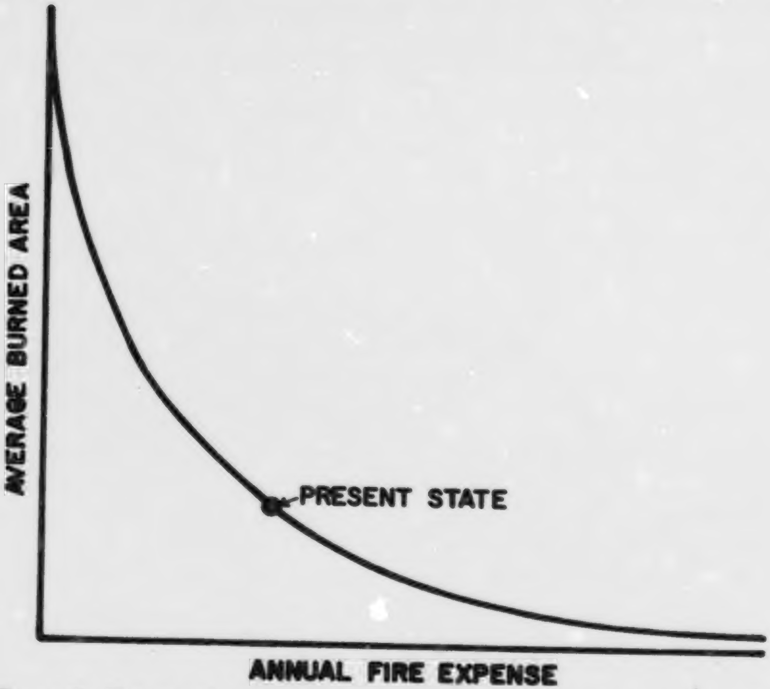

Figure 3. The relationship between average annual burned area and the annual fire control expense, with the supposed present state marked.

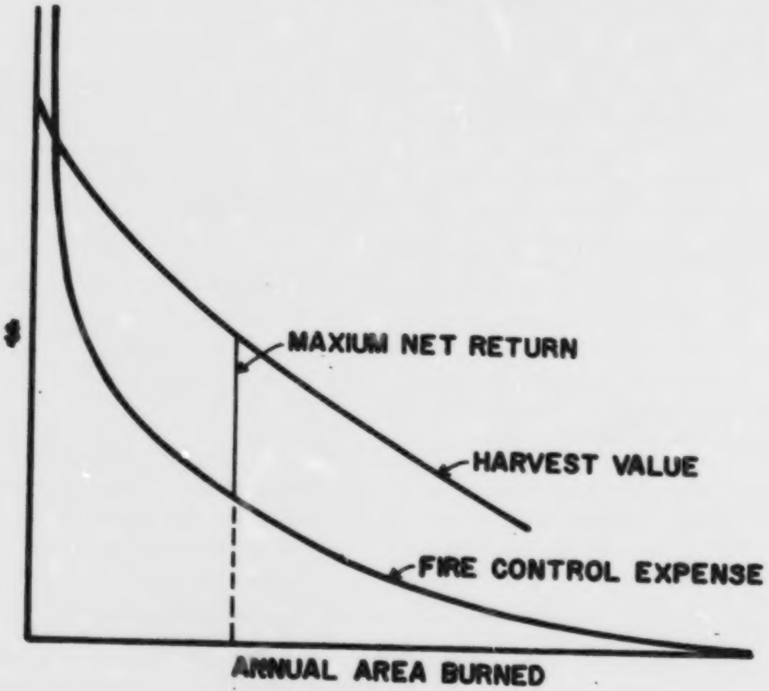

Figure 4. Diagram of the maximum net return as the maximum difference between harvest value and fire control expense, each plotted over annual area burned. Scales not qualified.

FURTHER CONCERNS

Some additional observations are appropriate. How does one relate individual fires or fire seasons to reduction in AAC? The answer lies again in timber supply projection. Current fires reduce the AAC in a stream of subsequent years, and new ways to quote this effect will be required, perhaps as the present value of a series of these future annual reductions.

This concept also very logically directs the fire control agency how to distribute its protection effort. First, it will protect the different kinds of forest more or less in proportion to their respective mean annual increments. Thus, if the harvest value curve (Fig. 4) lies all or in part below the curve of fire control cost, it may be difficult to find a comfortable level of fire control that will justify trying to protect the forest at all. This situation would obviously become more and more likely as one proceeds north in the boreal forest. Second, the agency will best protect those age classes that are in short supply in terms of future harvests. Thus, if the 40-year class is most poorly represented, the agency will save a 40-year-old stand even at the risk of losing a recent cutover that just cost $500 per hectare to regenerate. It appears then that investments in regeneration are properly regarded as distributed over the whole forest rather than as being concentrated on the particular hectares that happen to be treated.

It is worth repeating the point that loss is commensurate with demand. If there is no demand, presumably there can be no loss. Or, in the case of limited demand, it is clear from Figure 1 that a reduced but appreciable timber supply is available from any forest almost regardless of the amount of fire in it.

What about other uses and benefits of the forest and how they are affected by fire? It is fair to say that any forest use that depends on age can probably be analyzed in a similar manner, namely by always considering the whole forest rather than the burned area alone. As for natural benefits such as wildlife, water supply, oxygen balance, and the like, the simplest view is that there is no effect. The argument is simply that these are natural parts of ecosystems that have been cycled for millenia by random periodic fire; the patterns shift from place to place but the yields from the whole forest remain the same.

Then there is the problem of scale. What exactly is the whole forest? A large system is obviously implied, of a size that can accommodate the largest fires and the most-severe fire years without serious disruption. As the scale is reduced, a size is eventually reached when one good-sized fire could put a small forest operation out of commission. The viewpoint described here, therefore, is more appropriate for large fire control agencies and timber licenses than for small single-mill operations. For if no substitution from outside the unit is feasible, the problem seems almost more like one of insurance than of economics.

The concept of "maximized net return" carries with it a significant consequence. No longer can fire control be evaluated economically as a distinct operation separate from the rest of forestry. It must instead be regarded as just one component of forest management in general; evaluation and ultimate judgement rest logically at some higher level where all aspects of the forestry scene come together. The key word is integration.

CONCLUSION

Once the question of fire's impact is seriously raised in the open, it seems to me that there is only one way to tackle it, namely with objective logic, letting the chips fall where they may. If the answers are not in perfect agreement with conventional wisdom, this cannot be helped. Nevertheless, the whole question can be divided into two aspects, one of which may be considered "soft", the other "hard".

Consider first the economic aspect. If one accents the whole-forest/AAC concept just described, plus the principle of "maximized net return", it is clear that the value placed on the harvest is the crucial factor. Given the potential range in the value of a cubic metre of wood for protection purposes, the result of any such analysis will depend overwhelmingly on the unit value chosen. Can the economists agree on a common yardstick? Even if they could and it could be proved that the fire control effort was either too great or too small, no one is obliged to change his ways. The idea of maximized net return is as old as commerce itself in human affairs and governs various levels of our economy. Nevertheless, social and environmental concerns, acting through the political process, may control what is done about forest fire just as much as rational economic analysis. The whole economic side of the question is, in effect, probably rather "soft".

The timber supply aspect of fire's impact is, by contrast, a very "hard" issue indeed. Only the coolest of logic will suffice, it seems to me, when analyzing the impact of fire on what is the lifeblood of the forest industry, namely its annual allowable cut. The clear message from this analysis is that the correct measure of fire's impact is not the fire-killed timber, but rather the reduction in the annual harvest. And the true business of the fire control agencies is the protection of that annual harvest.

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POLITICAL IMPLICATIONS OF FIRE MANAGEMENT

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INTRODUCTION

There are a number of definitions for politics in the dictionary. The one I like most and feel is most applicable to our business is one used by John F. Marker and James Fazio in a paper under the same title as this one, delivered to the National Convention of the Society of American Foresters in Spokane in 1980. They defined politics as "the science governing and controlling governmental policy and that of regulating and controlling people." The authors went on to point out that forest managers have discovered that our professional decisions are not based on technical considerations alone. In other words, welcome to the real world.

Implications, on the other hand, are defined as the act of involvement, entanglement necessary as a circumstance, condition, or effect.

Considering that most of us in the fire business are involved in management of at least some public land and that, regardless of land status, many of our actions or inactions are subject to public view and often public criticism, an awareness of the political scene, what it means, and its implications is a must. What is obvious is that when the chips are down in a bad fire scenario, both the fire manager and the politician become front and center. What is not so obvious is that once a state of normality is reinstated the fire manager recedes to the background and often into obscurity. This is a trend that must be reversed.

The first thing I want to discuss from the standpoint of political implications of fire management is my home base, the province of Alberta. Because the first 3 years of this decade can be termed no less than a disaster from the standpoint of forest fire losses, we have learned some important and valuable lessons in terms of both the technical and the managerial phases of the program. Before doing so, however, in order to set the scene for what I have to say about Alberta in the 1980s, a few facts and figures are necessary for the benefit of those of you who may not be familiar with the province.

Alberta is one of two landlocked provinces in Canada and has long been known for its pioneer industry, agriculture, the foundation of its economy. More recently over the past three and a half decades, the province has become better known for its position as a developer, producer, and supplier of petroleum products and since the 1960s has enjoyed its status of being a "have" province. This is evidenced by the $13 billion Heritage Savings and Trust Fund.

Where then does this leave forestry and the forest industry? Alberta is officially classified as a prairie province, yet what is surprising to many people is the fact that over two-thirds of the province is forested. As a result we have a mandate area for forest protection of approximately 39 million hectares or 95 million acres. Although not all of the forested area comprises productive forest land, the significance of forestry in the province may best be appreciated by considering the following points.

- The present level of timber harvest in Alberta is approximately 7 million m^3, fourth-best in Canada behind British Columbia, Ontario, and Quebec.
- This past year the province crossed the threshold of 1 billion board feet of lumber production.
- The value of forest production exceeds a half-billion dollars per year.
- Approximately 6500 person-years of employment are generated by the industry.
- Probably even more significant is the fact that Alberta is one of the few areas in Canada that is not either totally committed or over-committed in terms of its annual allowable cut. Therefore we look forward to expansion by the industry in years to come and, projecting into the 21st century if there are no major deletions in the forest land base and providing we are successful in minimizing losses from fire, insects, and disease, we can optimistically look at increasing our forest industry by eight to nine times its present size.

- Over and above the forest industrial benefits, there are many other values at risk that form an important consideration in our fire management policy and strategy. I do not intend to get into these in detail other than to mention a few—fish and wildlife resource, water resources, and of course, forest recreation values.

FIRE MANAGEMENT IN ALBERTA

In the decade preceding the 1980s, the Alberta Forest Service (AFS) had made what it considered major strides in achieving an effective fire management program. During that period fire losses had been reduced to approximately 44 000 ha per year (108 000 acres) from historical levels of approximately 10 times that much. I certainly would not want to imply that complacency had set in, but at the same time we were in no way either mentally or physically prepared for the onslaught of fire activity that we were about to face.

The 1980s brought with them an extended drought that had not been experienced since the 19th century. What would occur over the course of the 1980, 1981, and 1982 fire seasons in terms of fire ignition, fire weather, fire behavior, lightning intensity, and so on was beyond our wildest imagination.

I do not intend to supply a detailed blow-by-blow description of what took place during these three worst seasons; it will suffice to summarize as follows:

- average number of fire starts almost doubled from 720 to almost 1400;

- lightning-caused or naturally caused fires, which normally account for about 45% of our starts, increased to 58%;

- average fire losses increased from 44 000 ha to over 873 000 ha;

- utilization of rotary aircraft zoomed to 37 000 hours in 1982;

- expenditures for forest fire suppression, which in the 1970s averaged less than $5 million annually, averaged over the 3-year siege in excess of $57 million annually.

In summary, the final toll for the 3 years collectively was:

- a total of 4181 fire starts;

- over 2.5 million ha (6.4 million acres) lost and a volume of over 73 million m^3;

- over $172 million were spent on direct fire operations.

To appreciate the significance of the suppression expenditure, one only has to look at the previous 50-year fire history of the AFS, in which a combined total of approximately $70 million was spent on fire operations. In other words, in 3 short years we exceeded our 50-year expenditure by some $100 million.

To add insult to injury, the annual fire loss exceeded our allowable losses of 0.1% by 22 times over the 3-year period. Significant change to our fire management policy therefore became a must. Fortunately from our standpoint, the need for change was recognized and endorsed at the political level.

REACTIONS OF THE POLITICIAN

One may ask just what kind of reaction we got from the government with respect to the fire problem. The most significant factor was that despite a number of concerns, the overall position displayed by the provincial government was one of solid support. Whereas they did not appreciate what was taking place, they seemed to recognize the severity of the drought along with the fact that we were generally successful in restricting the losses in our more valuable areas to a minimum.

The support by the government could not have been better exhibited than by the number of budget enrichments that took place following each of the disastrous years, resulting in our greatly increased capability to deliver our fire management program. Since the beginning of the siege in 1980 we have seen the following additions to the program.

- Increase of our air tanker fleet by adding three B-26s and three DC-6s, bringing the total fleet from 11 to 17.

- Construction of two new primary retardant bases, bringing the total in the province to 15.

- Construction of a number of initial-attack bases and staging camps throughout our protection area.

- The addition of two lookout detection facilities.

- The expansion of our helitack program from one to nine eight-man crews, each complete with a medium-sized rotary-wing.

- The development of rappelling capability for some of our helitack crews that began this past fire season and included a fully modern three mock-up, 60-foot training tower at our Hinton Training School.

- The replacement of our obsolete teletype system with a minicomputerized switching system.

- Major additions to our fire line communications capability, including two multicampaign fire kits based on the Ontario system.

- The installation of one of the most sophisticated lightning detection systems in the world from Lightning Protection Ltd., including seven direction finders, a position analyzer at provincial headquarters, and real-time remote display processors at each of our field forest headquarters and at provincial headquarters.

- The establishment of five remote automatic weather stations throughout the northern half of the province, where fire weather information systems were considered deficient.

- A considerable amount of fire line equipment too numerous and detailed to mention.

- A system of 14 stand-alone Apple III microcomputers for the assimilation of fire information.

The list goes on and on, but suffice it to say that the total one-time capitalized costs of these improvements amounts to approximately $6 million while the operating budget has been increased from just under $10 million to approximately $23 million (an increase of 130%).

All the above examples serve to illustrate that we are no different than anybody else in the fire business. In other words, we gain improvements to our program after we have suffered noticeable losses. The question one must ask is why? This is similar to the old adage of locking the barn door after the horses are gone. Obviously the fire management community must reverse the trend by developing the capability to sell its needs in advance of a catastrophe.

Over and above the funding support, I mentioned earlier that there were a number of concerns on behalf of the elected representatives. I would not pretend to be in the know as to what all these concerns are; however, here is a sampling of some of the perceptions at the political level.

1. First of all there was concern at the senior-most level of the department that we were not anticipating properly and hence were unable to provide quick-enough response.

2. Although the government continued to increase its financial commitment to the program after each bad year, the situation did not improve. The government felt that with the improvement made we should have been capable of reducing losses to an acceptable minimum. Instead each year we came back to the well for more. It is not difficult to perceive how a situation of mistrust could develop under these circumstances.

3. There was a feeling that spending on campaign fires was overly excessive. As well, the word was out that we were not even capable of determining what our expenditures were until long after the bills came in.

At this point you may wonder how we were able to continue the level of resource commitment to our fire problem. Basically there were three major factors in our favor. The first was that the level of funding for fire management in Alberta has been made possible only because of a vibrant oil and gas industry that has placed the province in very good financial stead. The second factor, which is a product of the first, was that the province entered a deep financial recession that had severely affected not only the oil and gas industry but also the many support industries associated with it. Therefore the major fire activity provided much-needed work for fire fighters as well as for the aviation, heavy equipment, and supply industries. The government, although not appreciative of the financial situation with respect to our fire program, was astute enough to recognize the secondary benefits accruing to the private sector. The third factor was a good understanding at the political level of the values being threatened.

What have we as fire managers done to respond to some of these concerns and reactions at the political level?

1. First of all, in 1982 we introduced an Escaped Fire Analysis Strategy (EFAS). This strategy has enabled us to define throughout all levels of the organization a common denominator as to values at risk, fire strategy and tactics, resource commitments, and of course, expenditures.

2. Subsequent to the EFAS we have introduced controls on the number of helicopters we can deploy to any one project fire. This was necessary as the helicopter is the most expensive tool that we deploy.

3. We have de-emphasized our capital spending program for facilities and put the majority of our emphasis onto the operational arena, concentrating on initial attack.

4. We have refined our fire cost reporting system so that we can accurately determine on a daily basis the level of spending and the direction we are heading.

5. We have instituted a monthly reporting system during the fire season, through the most senior levels of government, as to what is taking place in the fire management scene.

The adoption of these measures has in my opinion gone a long way toward winning back some of the credibility we had lost.

CANADIAN FIRE MANAGEMENT SCENE

Turning briefly to the Canadian fire scene, there are two very significant events that have taken place recently that had major political involvement and will continue to do so through the years.

The first was the establishment of the Canadian Interagency Forest Fire Centre. It was through the persistent and dedicated efforts of fire managers across the country, followed by approval and support at the political level, that the center was established a little over a year ago. As this will be a subject of a later paper, I do not intend to go into detail now other than to say that the center provides a marked improvement in our ability not only to respond to heavy forest fire loads across the country but also to improve the level of fire management on a national basis. Furthermore, the establishment of this center brings together all fire management agencies across the country to a common denominator regardless of the politics of a particular province or territory.

The second major happening is the cooperative supply agreement for CL-215 water bombers, which will lead to the establishment of a national air tanker fleet. The establishment of a national fleet of air tankers has been the subject of hot debate as well as pursuit throughout the fire management community for many years. There were many people, myself included, that were skeptical as to whether the deal could be pulled off.

There are many pros and cons involving the agreement and, more specifically, the airplane itself that I do not intend to get into. Instead, let's briefly look at the politics of the situation.

First, from the standpoint of the federal government there is no question that the biggest incentive for its involvement was to provide a major stimulus to the ailing Canadair Corporation. Secondly, it provided an avenue for the federal government to address its need to contribute to the forestry sector, and in particular, forest fire management. From the provincial or agency scene, it was an opportunity for those who participated not only to upgrade their fleets, but also to gain a piece of the federal pie.

There are of course many arguments concerning the agreement itself, such as the trade-off between land-based retardant operations and skimmer operations and the suitability of the airplane itself, in which we have all been involved and for that matter are still involved to some degree. I suggest it is time we put these arguments behind us, for to continue the debate is to my mind counter-productive. I believe what we have to realize, whether we like or dislike the CL-215, is that aside from augmenting provincial fleets, we will have a national tanker fleet that will benefit in the long run not only those agencies that are directly participating, but also those that are not.

FUTURE CHALLENGES THAT INTERFACE WITH THE POLITICAL ARENA

Over and above technical change, there are a number of challenges that we as fire managers must face, several of which will interface with the political arena. Some of the more important challenges, which I see as being of an immediate or urgent nature, are noted below.

Budget

The first area is that of fire management budgets. Along with the downturn in the economy, we are now facing flat line or even decreasing budgets and staff reductions. Despite this rather unpleasant fact of life, we have to take every opportunity to sell the principle that dollars must be placed upfront in our programs so that we can maintain the maximum capability for detection and effective initial attack.

We must also take every opportunity of experiences, good or bad, that happen elsewhere; i.e., what happened in Australia in 1983 could happen here.

Once we have achieved adequate budgeting we must develop the capability of maintaining it during or after lean fire years. This can be done through well-documented reminders of situations past or elsewhere. Probably one of the best ways of maintaining budgets is to declare surpluses quickly at the conclusion of our good years as opposed to channeling these surplus funds into other areas. This upfront method establishes credibility with the financial people and, if you can establish that you are only using funds as needed, there is a much lesser risk of your future budget bases being eroded.

The area of cost effectiveness cannot be underestimated. In these days of economic restraints we must continue to strive to do the job better and at the same time for less cost.

Values at Risk

The subject of values at risk has already been discussed in detail; however, I cannot emphasize enough the importance of the fire management community coming to grips with it. Values at risk have been identified as a major research priority for many years, yet progress has been very limited.

As we progress through the 1980s and as fire fighting becomes more in the public view, it only stands to reason that we will be held more accountable for our actions. Therefore we must be able to respond with good cost-benefit documentation as to trade-offs between substantive action and letting certain fires go. There are currently some good research efforts under way addressing the values at risk problem; however, as these will likely take years to complete, I'm afraid we cannot afford to wait long-term for results. We must establish at least interim procedures or else face the reality that our fire management strategy will be formulated by people other than fire managers.

Fire Prevention

Fire management through the public and the politician's eye often does not go beyond fire control. One thing that we are doing in Alberta is placing more of this responsibility up front by transferring fire prevention responsibilities to the land user so that prevention measures are built-in from the start.

To my mind, however, this is only the tip of the iceberg. For example, vast areas of lodgepole pine stands throughout the inland empire have been devastated by the mountain pine beetle, meaning not only loss of the resource but also significant buildups in fire hazard. In Alberta we have invested over $4 million in a control program that has thus far been successful in curbing the northern spread of the beetle. Yet despite the success of this program, we have large areas of dead timber fuel accumulations left that pose a very serious danger. On a broader scale we have significant areas of forest that are unloggable or are tied up in natural areas, parks, and so on. We have been successful in controlling wildfire in these areas for many years so that today an asbestos forest theory is shared by many people outside the fire community. Yearly the situation becomes riper for catastrophic fire losses.

There are, to my mind, two choices. The first is to accept that wildfire is the only answer and simply not action such fires when they occur. Whereas this may be the preferable option under most circumstances, I'm afraid it is not the answer under extreme fire regimes.

The other option then is through prescribed burning. Since many of these stands can only be rejuvenated by fire, the ball is in our court to do something about it. There will be many difficult battles with those that do not want to see the area blackened. Our job will be first to convince those people that the way to avoid catastrophic situations is to introduce fire on a managed basis. If we can do this, then I am sure that we can overcome the politics of the situation simply because there will not be any.

Cooperation With Other Fire Management Agencies

The sharing of resources among agencies and among countries has proven to be a successful strategy over many years. The considerable amount of mutual aid provided through the Boise Interagency Fire Centre to several provinces and territories over the past four fire seasons is a good indication of what can be done.

The principle of mutual aid has been further strengthened over the past 18 months through such measures as the Canada-United States Forest Fire Fighting Assistance Arrangement, the establishment of the Canadian Interagency Forest Fire Centre, the Co-operative Supply Agreement leading to the establishment of a national air tanker fleet, and the Mutual Aid Resources Sharing Agreement.

Even with these principles firmly entrenched, however, there remains much work to be done. In Canada we must continue to strive for the development of national standards for training and equipment that will hopefully retain some compatibility with standards in the U.S. The establishment of high-technology resources that are too expensive for any one agency to procure and maintain be of high order. Of particular concern to Alberta at this time is the development of a national capability for high-elevation infrared scanning similar to those systems developed by BIFC. There are of course many others.

One area that has created a problem of late is that of the interagency movement of human resources. During these days of recession and high unemployment, it makes little sense to the politician to import fire-fighting personnel when, in his eyes, this function could be filled from the ranks of the unemployed. This leaves the fire manager in a position of either putting the unemployed on the lines, usually with negative impacts, or simply deciding to do without. There is therefore a need to convince the political level that fire fighting is not ordinary labor, but instead a very skilled trade that cannot be fulfilled from the ranks of the unskilled unemployed.

Politics and Public Relations

Certainly any paper on politics and fire management would be remiss without mention of the necessity of good public relations. As this area has been the subject of several papers in the past, I believe it is not necessary to dwell on this aspect in detail. The importance of a good public relations program, including a well-informed public and well-informed politicians, should by now be an essential ingredient for the delivery of any creditable fire management program.

We must realize that often a politician's view or understanding of a fire management problem is through the eyes of the media. In the past, fire management personnel have been too busy to properly inform the media during times of conflagrations, and then once the smoke has cleared, the media has little interest in our problems. We must therefore seek every opportunity to develop a good rapport with the media. A well-informed media leads to a well-informed public and politician.

CONCLUSION

The above represents only a sampling of some of the more important issues upon which we as fire managers must place high priority in terms of our interface with the political arena. There are of course many other areas that we must tackle. If we approach these areas in an open, honest, and straightforward manner, complete with an awareness of the political implications, we should eventually be successful in overcoming many of the obstacles that currently confront us.

INITIAL-ATTACK INITIATIVES IN ALBERTA: A RESPONSE TO THE 1980s

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INTRODUCTION

From the fall of 1978 to the spring of 1983 climatic conditions caused severe moisture deficiency in Alberta's forests during critical periods of the fire season. This climatic situation, coupled with fuel and geographical conditions, culminated in record fire seasons in Alberta. Every season from 1979 to 1982 set new records of one dubious sort or another. Fire incidence soured to unheard-of numbers and multistart situations took on new meanings. Hectares burnt set all-time records, direct suppression costs hit national records, and long-term averages in all facets of fire suppression were shattered. Fire spread rates and resistance to control factors were phenomenal in terms of previous experience. The incidence and severity of fires in the 1980s soon stripped operational and organizational capabilities, especially initial-attack resources during massive multistart situations. In addition, our conventional resource staging strategies could not place resources on fires in short-enough attack times to cope with the rapid spread rates. Although the Alberta Forest Service (AFS) had initial attack systems in the early 1980s, they were insufficient to deal with the problems encountered during this period.

In addition to the operational problems there was a genuine concern for the future of timber management planning and the expansion potential for the forest industry in Alberta. The desire of the AFS to enhance the economic base derived from utilization of the forest resources, both for recreation and wood fiber, meant that a radical adjustment in strategy would be necessary to reduce potential catastrophic fire losses under similar conditions in the future. Without the assurance of a better level of forest protection from wildfire, expansion of the economic base from the boreal timber resources would not be possible.

This paper addresses the situation of the early 1980s and outlines the new presuppression strategy adopted by the AFS to meet future severe fire situations.

THE SITUATION, 1979-1982

Any serious fire control strategy must recognize geographical and climatic factors that affect fire incidence and fire spread. Can the geographical factors and, more significantly, the climatic factors that contributed to the large fires of 1980–82 be identified?

Geographical factors

The most obvious feature of Alberta's geography is the range of mountains forming much of its western boundary. What effect do the mountains have on fire incidence and fire behavior?

Lee cyclogenesis

Cyclogenesis (development of low-pressure areas) to the lee of any major mountain range is a well-known and well-documented phenomenon. Under conditions of cross barrier flow (Fig. 1) the downwind region is a favored area for pressure falls and consequently the development of cyclonic centers. Such low-pressure areas tend to cause an increase in the westerly surface winds blowing in the mountainous areas. Such winds, being frequently dry, increase the fire danger. In the eastern part of the province brisk southerlies are induced (Fig. 2). The low-pressure areas developing over the province move eastward or northeastward when the associated perturbation at upper levels moves across the mountains. Thus eastern portions of the province may experience a wind shift from brisk southerly to brisk southwesterly. Thus in eastern Alberta major fire runs

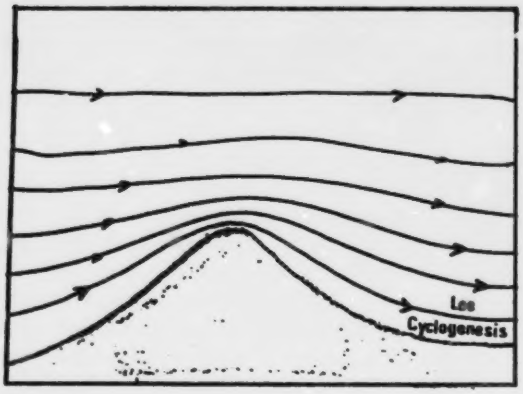

Figure 1. Favored area for lee cyclogenesis.

frequently move from south to north. With the wind shift to the west, the east flank becomes the fire front, as happened in 1980 on fire DND-4 (Alexander et al. 1983). In western Alberta on the other hand, major fire runs are almost exclusively from west to east.

Day lightning

Meteorologists agree that increased convective activity is associated with lee cyclogenesis. The well-documented hail area east of Rocky Mountain House is an example. The lightning associated with such convective activity is often accompanied by precipitation; however, under dry conditions and in the initial stages, the lee cyclogenesis is accompanied by dry lightning.

The mountains, then, contribute to both an increase in fire danger and fire risk.

Fuel continuity

The forested areas of northern Alberta, the western Northwest Territories, and western Saskatchewan have no effective large-scale fuel breaks. In most of British Columbia and the foothill forests of Alberta there are mountain ranges oriented perpendicular to the prevailing winds. These ranges act as effective fuel breaks in all but extreme fire conditions. The extreme northeastern corner of Alberta and much of northern Saskatchewan have numerous lakes, a legacy of the last ice age. These lakes, again, are oriented in a northwest-southeast direction and act as fuel breaks.

The only natural fuel breaks in northern Alberta are several hilly areas (Caribou Mountains, Birch Mountains) and the rivers. Experience has shown that these features do not act as effective fuel breaks under vigorous fire conditions. This lack of natural fuel breaks leads to the possibility of single fires growing to immense sizes. Single fires in excess of 1.5 million ha have been documented (Hay River 16-81).

In retrospect it is clear that these geographical factors played a role in the severe fire situations of 1980-1982. In 1980 and 1981 lee cyclogenesis contributed to the high winds on the worst burning days, and in 1982 it was a factor in the "lightning bust" that produced the multistart situation in June. Because of fuel continuity, several fires in the 1980 and 1981 seasons exceeded 100 000 ha.

Climatic factors

With the exception of a few years such as 1968, 1971, and 1979, the 1960s and 1970s were relatively quiet years in Alberta in terms of hectares burnt. This is in contrast to what happened in the 1930s, 1940s, 1950s, and early 1980s. Is there a meteorological or climatological basis for this difference? The AFS maintains a running plot of the 500-mb anomaly (Fig. 3). The problems of the early 1980s were clearly associated with prolonged periods and subsequent breakdown of positive 500-mb anomalies. An analysis of the early 1980s (1980-82) shows that there was a prolonged period (10 or more consecutive days) of a positive 500-mb anomaly in each year. The hectarage lost appears to be a function of number of ongoing fires at the breakdown of the anomaly and the rapidity with which the breakdown comes. An example of one prolonged anomaly is shown in Figure 4 (Nimchuk 1983).

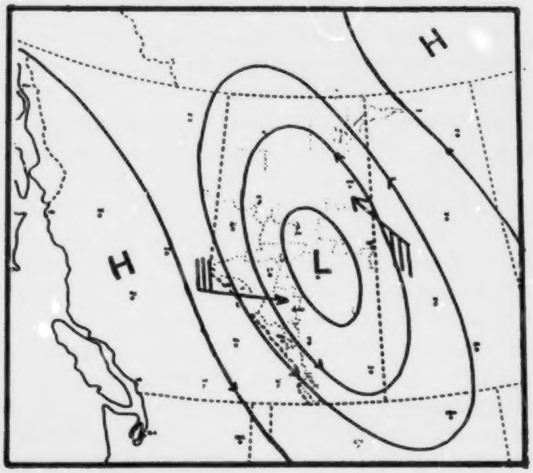

Figure 2. Surface weather map illustrating lee cyclogenesis.

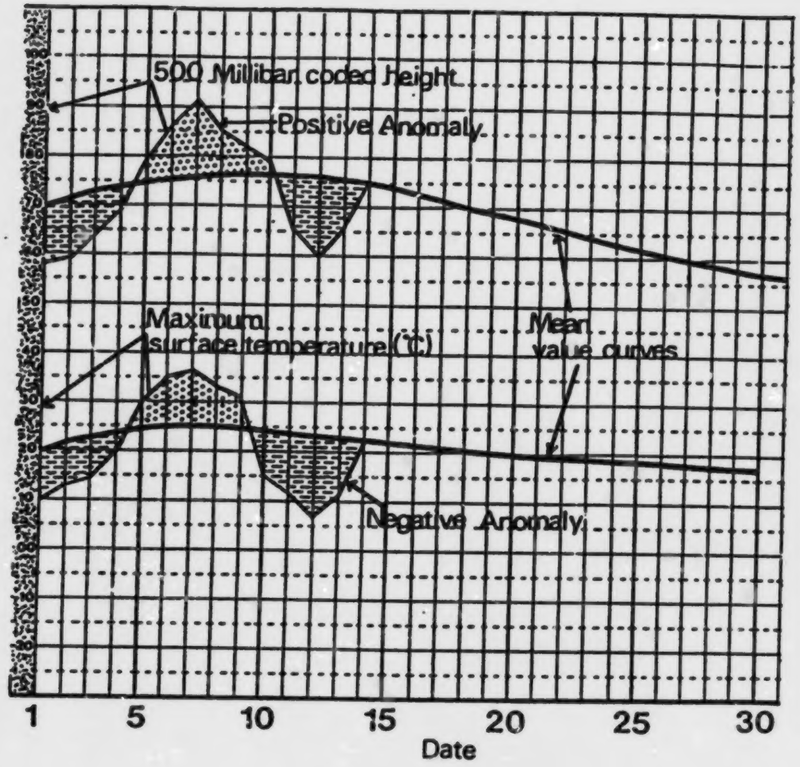

Figure 3. Example of 500-mb anomaly and maximum surface temperature anomaly.

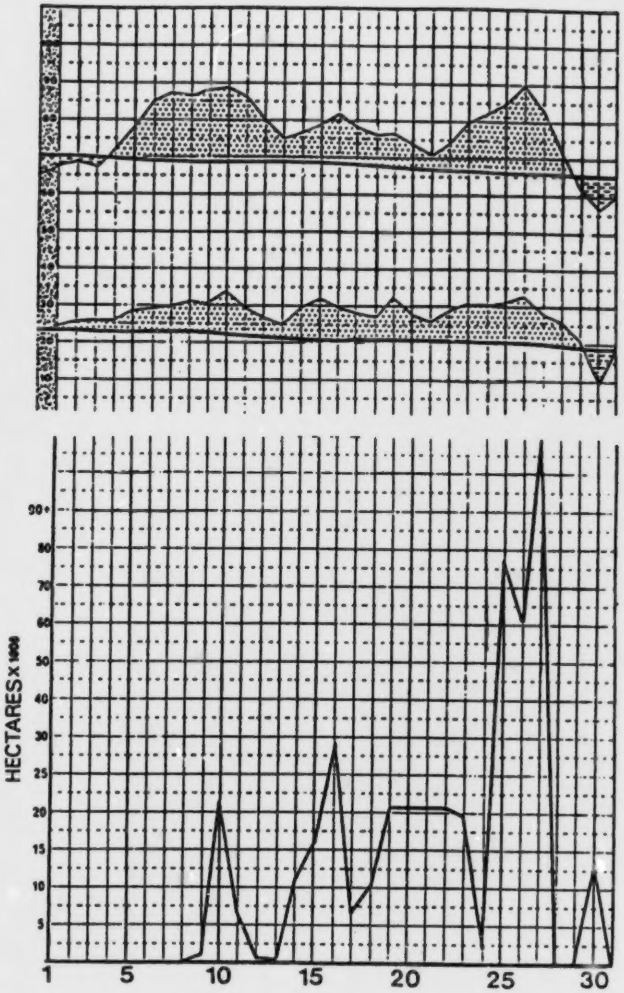

Figure 4. August 1981, 500-mb surface maximum anomaly (top) and area burnt (below).

By and large, with the exception of the years noted, the 1960s and 1970s were characterized by fluctuations of the 500-mb height around the normal with few or no extended positive anomalies. Precipitation during these decades was well distributed throughout the fire season. In contrast, in the early 1980s precipitation events have shown a different pattern: short periods with light precipitation interspersed with short periods of copious precipitation.

There appears to be some agreement among climatological researchers that North America is entering into a period where climatic fluctuations are normal. This implies that wide year-to-year and place-to-place variations in the weather should be expected. The low fire year of 1983 in Alberta, the floods in Arizona, and the fire problems in central and eastern Canada in 1983 seem to support this concept of dramatic fluctuations.

In terms of fire management this fluctuation concept implies that there will probably be a higher frequency of extended periods of 500-mb anomalies somewhere in North America. This in turn implies fire problems in the affected area. Although the 500-mb data do not form a direct input to the AFS Preparedness System, fire control managers use the forecasted trends as guides for resource deployment.

Fire occurrence

In the 10-year period 1969–1978 Alberta experienced an average of 675 fires per season. The previous 20-year peak incidence was 906 fires in 1971. During the seasons 1979–1982 there was an average occurrence of 1280 fires per season with a peak of 1522 fires in 1981 (Fig. 5). Hectares burned during the same 10-year period averaged 25 000 per season with a peak of 60 000 ha in 1971. During the period 1979–1982 the average was 718 000 ha burned per season with a peak of 1 365 581 in 1981 (Fig. 6). The early part of the 1980s certainly saw the most severe fire situation since the introduction of modern forest protection in Alberta.

In addition to the large hectarage losses, a new ignition record was set. In one evening during June 1982 there were 125 dry lightning starts spread over five forest regions in northern Alberta. This situation gave a new perspective to the multistart situation in the boreal forest. In addition to record starts the fire behavior was very severe due to low fuel moisture content. Crowning occurred within 3 minutes of ignition in several cases.

The high incidence and severe fire behavior, occurring in high priority areas, resulted in a record direct suppression cost of $63.5 million in 1982. The average direct fire costs for the 10-year period 1969–1978 was $3.8 million per season. In contrast the average direct fire costs including short-term presuppression readiness (man-up) for the period 1979–1983 was $32.5 million per season (Fig. 7). These cost escalations, coupled with forest-resource losses, flagged the need to make strategic and tactical adjustments to the fire-control organization.

THE PLANNED RESPONSE

Most fire agencies have argued over the years that more funding for presuppression or organizational capability prior to fire starts would significantly reduce subsequent direct fire suppression costs.

Agencies in the fire business have never quite achieved the level of funding required to reach the capability level perceived as necessary. In fact, only limited work has been done to determine just what capability level is necessary or desirable to meet agency concerns, and what level of control should be established as an objective. As all fire personnel are aware, it is a very small fraction of the total fire incidence that results in both highest cost and highest loss. Each loss percentage point successfully reduced after a certain level becomes extremely costly.

PRESUPPRESSION PREPAREDNESS SYSTEM

System goals and development

Concerns for the severe losses and high expenditures of the 1979-82 period prompted senior management of the AFS to support the development of a new presuppression strategy with a dramatic increase in "up front" expenditures. The system was developed on the basis of the following four goals:

a) reduction in the number of destructive campaign fires, even under very severe hazard conditions and incidence patterns;

b) reduction of the overall direct-suppression cost and resource losses without increasing presuppression cost to the point of diminishing returns;

c) the design of a system that could be implemented on a forest-by-forest basis, would be very reactive to climate changes especially escalating hazard, and could be readily audited on a provincial basis; and

d) the ability to evaluate the system in the 1983 season in order to generate immediate results and have a relative feel for potential success expectations.

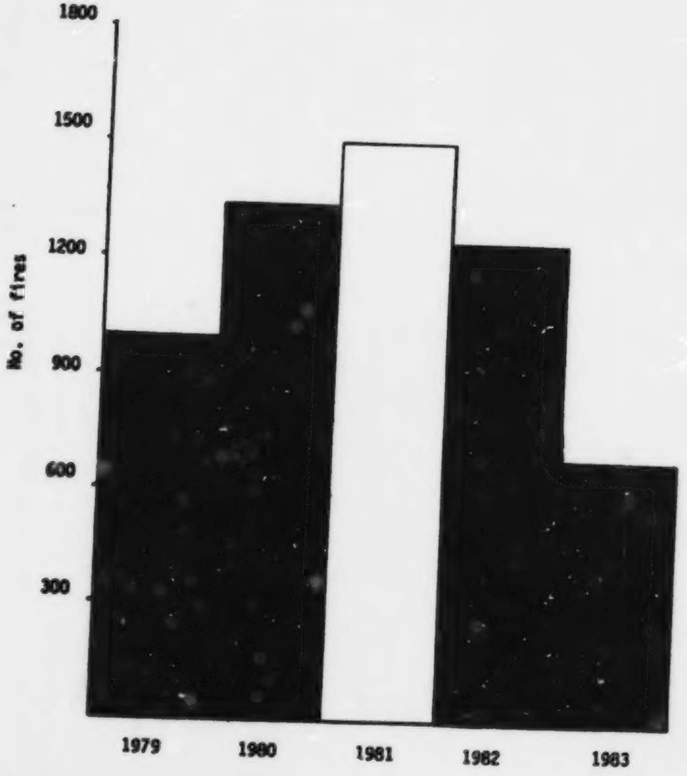

Figure 5. Annual fire incidence in Alberta, 1979-83.

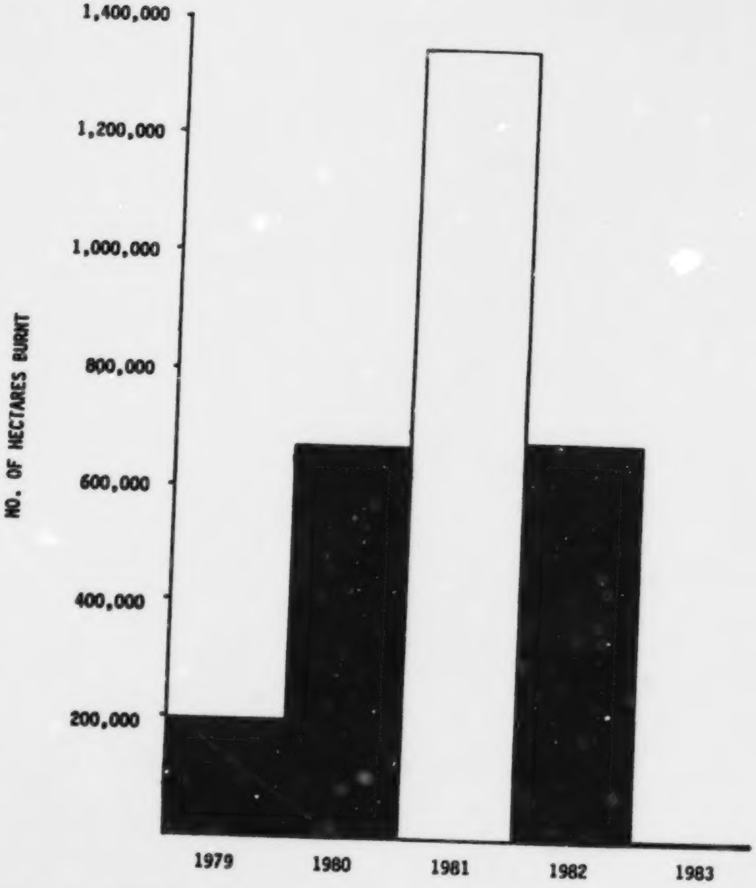

Figure 6. Annual area burnt in Alberta, 1979-83.

In an effort to meet these goals, the following factors were integrated into the system:

a) recognition of the key thresholds of the Canadian Fire Weather Indices that indicate severe fire ignition and fire-behavior potential in Alberta (Fig. 8).

b) basic identification of fuel types with respect to their continuity, crowning potential, and resistance to control.

c) the determination of acceptable initial-attack times as related to the potential fire behavior of identified fuel types.

d) identification of predetermined strategic initial-attack centers that provide optimum coverage of the forested areas. These centers to be activated as determined by hazard, values at risk, and man-up levels.

e) recognition and identification of high-value, high-priority areas within each forested area.

f) all resources committed to initial attack to be supplied with adequate transportation in order to meet the initial-attack standards. In Alberta's forested areas, rotary-wing transportation is normally the most efficient means available.

g) initial-attack resources, based on predicted hazard, to be in place in sufficient quantities at strategic locations prior to commencement of a fire outbreak. This should be most effective in reducing assembly and travel time, thereby minimizing the risk of large fire losses caused by initial-attack delays, particularly during multifire start situations.

h) recognition that when large areas of the province are under high manning levels it may be impossible to supply all resources required by the tables. In such cases, forests are to consult with provincial headquarters, which will decide on resource allocation.

As resource levels are governed by supply limitations and fiscal constraints, it is possible that instances will occur where the manning of all required initial-attack centers will be impossible. Therefore, the fire manager must consider the existing fuel types and resource values when deciding which centers will be manned. In general terms, the system works as follows: as the fire danger increases, additional suppression resources are committed and strategically placed to reduce travel time to a potential fire start; as the fire danger decreases, suppression resource levels are reduced and travel times are relaxed in recognition of the lower potential for fire-control problems. The system works on a forest-by-forest basis but is coordinated interforest and provincially by way of a reporting system whereby all fire managers in the province are aware of the total provincial man-up and deployment.

Man-up tables and implementation

The operational implementation of the system is facilitated by a set of tables to be used as guides by all fire managers. Implementation is in two phases: a resource buildup portion (man-up) and deployment. In the man-up phase short-term suppression resources are added to the basic seasonal (budgeted) organizational capability. The deployment strategy places resources in the risk areas based on a predetermined attack time necessary to meet anticipated fire incidence and spread-rate potential.

Man-up procedure

Man-up is determined by fire danger classes (based on the Canadian Forest Fire Weather Index System), fire incidence, and severity potential. The man-up preparedness level for the next day is calculated for each forest unit using predicted highest average FFMC and BUI values. These predicted index values are determined by entering the 24-hour forecasts of weather parameters into an Apple III microcomputer in which the current day's index values are already stored. The forest protection officer then has about 18–20 hours lead time to assemble and deploy resources prior to the peak of the next burning period.

Six levels of preparedness are used, based on the indexes that indicate fire ignition potential and fire-behavior severity (Table 1). The same range of FFMC and BUI values were used to develop initial-attack times (getaway and travel time) outlined in Table 2. As fire weather severity rises the initial-attack time decreases. Suppression resources are assigned to each level indicating the minimum amount of each resource to be placed on standby (man-up) under each level. Each level also has mandatory supervision tied to resource buildup to ensure that sound fire experience and capability are available (Table 3).

Deployment procedure

A series of attack centers has been defined. Any base or area used to stage resources becomes an attack center. They may be established facilities, administration points, or a helispot in the forest where resources can be staged on a daily basis. Attack centers are generally

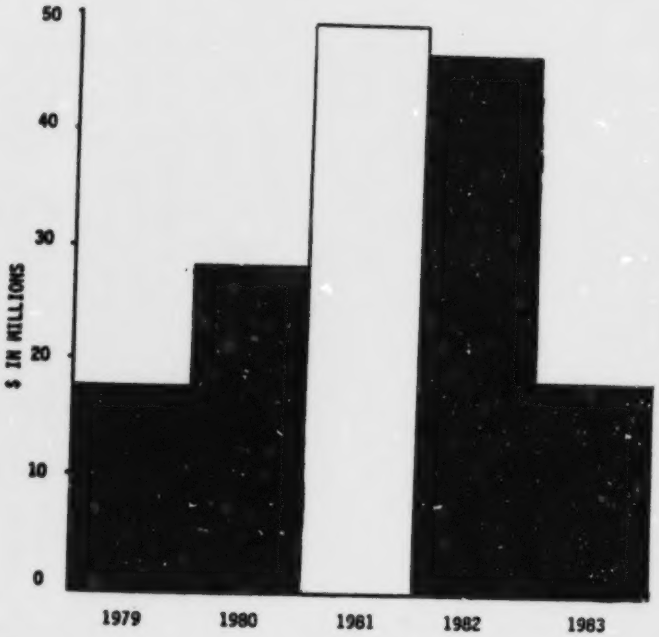

Figure 7. Suppression costs in Alberta, 1979–83.

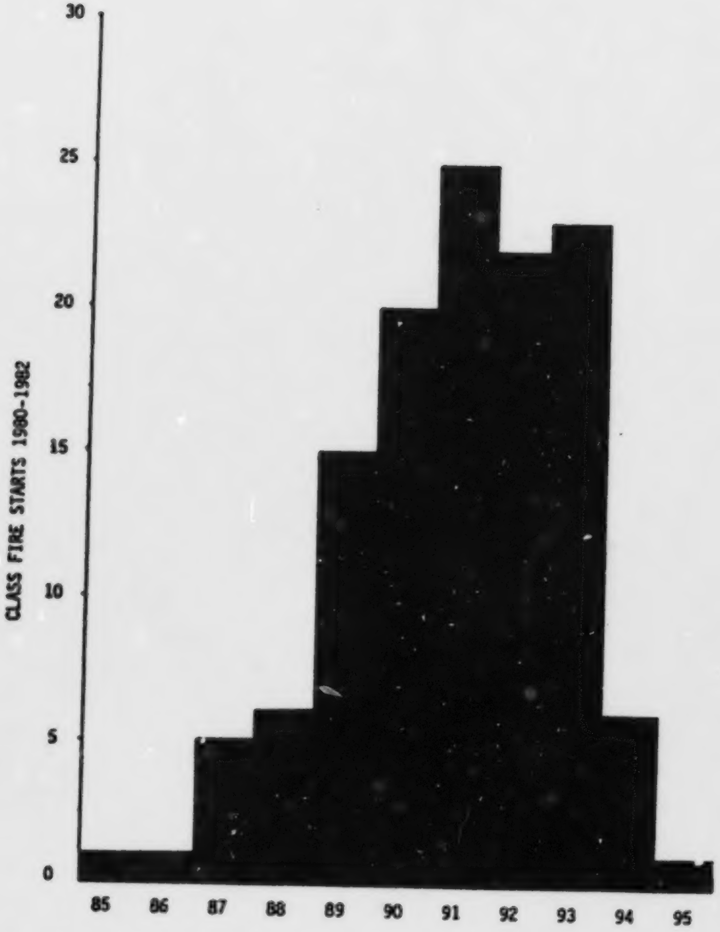

Figure 8. Class E fire starts in Alberta related to FFMC classes, 1980–82.

Table 1. Preparedness levels

Level of preparedness	FFMC	BUI/D.C.	Risk
Level VI	89+	85/300+	Risk not a factor
Level V	89+	85+	Risk not a factor
Level IV	89+	61-85	Risk not a factor
Level IV	86-88	61-85	High risk
Level III	86-88	61-85	Risk not a factor
Level III	Less than 80	Greater than 85	Risk not a factor
Level III	89+	Less than 61	Risk not a factor
Level II	85-88	Less than 60	High risk
Level I	Less than 85	Less than 41	Risk not a factor

Table 2. Acceptable attack time from point of dispatch and initial attack standards

To first action on fire	FFMC	BUI/D.C.	Risk
15 minutes	89+	85/300+	Risk not a factor
15 minutes	89+	85+	Risk not a factor
15 minutes	89+	61-85	Risk not a factor
15 minutes	86-88	61-85	High risk
30 minutes	86-88	61-85	Risk not a factor
30 minutes	Less than 80	Greater than 85	Risk not a factor
30 minutes	89+	Less than 61	Risk not a factor
30 minutes	85-88	41-60	High risk
60 minutes	Less than 85	Less than 41	Risk not a factor

Initial attack objective	Getaway time	Travel time
15 minutes	3 minutes	12 minutes
30 minutes	5 minutes	25 minutes
60 minutes	10 minutes	50 minutes

Table 3. Preparedness level resource buildup

Preparedness Level	Resource buildup
Level VI	Forest seasonal initial-attack crews 8 - eight-man squads 3 - 25-man crews 8[a] - light rotary-wing 5 - medium rotary-wing Final cost $53 017
Level V	Forest seasonal initial-attack crews 5 - eight-man squads 2 - 25-man crews 8[a] - light rotary-wing 2 - medium rotary-wing Final cost $33 531
Level IV	Forest seasonal initial-attack crews 3 - eight-man squads 6[a] - light rotary-wing 1 - medium rotary-wing 2 - 25-man crews Final cost $22 991
Level III	Forest seasonal initial-attack crews 3 - eight-man squads 6[a] - light rotary-wing Final cost $15 875
Level II	Forest seasonal initial-attack crews 3 - eight-man squads 4[a] - light rotary-wing Final cost $7 935
Level I	Forest Seasonal initial-attack crews

[a] Based on 3 initial-attack crews per forest.

located on the basis of best coverage of the area and are manned on the basis of historical and predicted risk potential and priorities of values at risk. The choice of attack centers to be manned on any given day depends on preparedness level, forest priorities, and attack times prescribed. The concept is that as fire danger level rises, the attack center's sphere of influence shrinks so that the combined getaway time plus travel time equals the total attack time objective. For example, a 15-minute attack objective is made up of 3 minutes getaway and 12 minutes travel time. As the sphere shrinks more centers are activated until a maximum level of preparedness is attained. At this level it is possible to have a total forest covered with resources that will never be more than 15 minutes attack time from any fire start.

The strategy and all policies and procedures described in a general fashion in this paper are outlined in the complete *Pre-suppression Preparedness Manual.*

System testing

The system was initially developed in July 1982. Prior to field implementation it was subjected to a theoretical test using data from a specific day in 1982 with a record number of starts in one forest. On June 13, 1982, the province experienced 125 starts resulting in 21 Class E or major campaign fires. In order to establish a target and a check on the new presuppression system, one forest (Slave Lake) that had the most starts for the day (54) was chosen. Of the 54 fires 14 became major campaign fires. A computer spread and containment modeling was conducted with the following inputs:

a) representative weather parameters for Slave Lake Forest for June 13, 1982;

b) worst-case fuel type (black spruce) was assumed for all starts;

c) it was assumed that all starts occurred within a 6-hour period at the peak of the burning period.

The results indicated that with Level VI resources it would have been possible to successfully contain 39 fires in the 6-hour period.

The AFS is satisfied that Levels V and VI would have given an optimum capability to deal with the 1982 scenario, the worst outbreak of fires in a single day in recent history. The question may arise as to why the AFS should be satisfied with a containment of 39 fires (i.e., 15 escapes) under Level VI. It must be emphasized that for the purpose of the exercise the worst-possible conditions were assumed. In reality not all fire starts were in black spruce, some fires started outside the 6-hour frame, some received precipitation, and some occurred in conditions allowing control during the second burning period. In actual fact 14 of the 54 fires escaped initial attack and became Class E fires. This was under existing resource deployment at the time, which equates to about Level III under the new tables. It is felt that the escapes would have been reduced by 90% under the new system, netting only two fires of Class E status. Therefore, the AFS is confident it can bring the success rate up to the 98% level under the new system. Through priority assessment the 2% escaped fires should be held to low-value situations that need not be as actively suppressed, resulting in low direct suppression cost.

The AFS does not expect, nor should it be lured into feeling, that the system *per se* will solve all campaign fire problems; however, the system does provide the mechanism to accomplish the task at new success rates previously unachievable. There will still be large fires in Alberta, but with this new strategy and a sound priority and field fire assessment procedure, there should be dramatic strides in reducing loss from wildfires in critical value areas. The immediate aim is to see that presuppression costs of this system, plus direct suppression, are significantly lower than previous direct suppression costs in seasons with similar climatic circumstances.

THE 1983 EXPERIENCE

Although Alberta experienced a generally slow year in 1983 the early part of the season, up to June 10, was very dry and did produce significant fire weather and some starts that had potential. The overall season did not produce situations to test or strain the system or to confirm its benefits or shortcomings. Enough data were obtained, however, to be at least optimistic that the concept and general principles are valid. The system shows significant promise that it will meet identified objectives. In fact there were at least two or three specific multistart situations that tested the system and proved it successful. In one specific case a saving of $235 000 on a single day can be proven. In addition there were two Class E fires that had significant potential. Although initial attack failed in these two cases, the fires were caught in the second and third periods. This success can be attributed to immediate resource availability as a result of man-up situations, which allowed extremely rapid deployment of large quantities of resources within the first burning period. On DW4-09-83, a man-caused fire in Swan Hills, 30 cats, 10 rotary wing, eight 25-man crews, and 3 tanker groups were on the scene within 4 hours of initial-attack failure. This resulted in effective containment within the first burning period.

Costs of man-up in 1983 were $8.6 million, with direct suppression costs at $8.4 million. There were 736 fires to October 21, but only 2681 ha burnt. This total represents the lowest loss by fire in Alberta since 1962, when only 1864 ha were burnt with only 278 fires. The record does indicate a relative measure of success that is encouraging although inconclusive. Several weaknesses were identified with the system during 1983 that will be corrected to improve the 1984 operation. With the improvements and adjustments proposed it is felt that at least 20% could be cut from the man-up cost under similar conditions.

The major weaknesses in the system are as follows:

1. it requires a mechanism to build-down faster after significant precipitation. Tables tend to stall resource release when danger is on a downward trend.

2. the tables should differentiate between FFMC values of 89 and 90 and those in the 91+ range.

3. the man-up level recovers too quickly after a rainfall between Levels II and III.

4. it does not handle the spring fire danger situation, where only settlement and settlement fringe areas are involved.

5. it requires a cutback in fall periods to recognize seasonal situation where there is a shorter burning period and the fire season is on the decline, versus early summer where the season is just commencing.

CONCLUSION AND SUMMARY

Although the new presuppression preparedness system is not a panacea for all fire-suppression problems, we feel it is the most significant development in the past decade aimed at putting initial attack at a new, unheard-of level for potential success.

If proven to give us the success ratios we perceive possible, it will place the whole protection business on a new foundation of control that will provide for the building of a true fire management program allowing us to make rational decisions about the use of natural wildfire in meeting land management goals. This new system gives fire managers in Alberta the opportunity to prove the up-front theory of fire suppression. Failure of the initial-attack program certainly can not be placed on insufficient up-front funding, as our senior management and government have given us a much dreamed about opportunity to up-front our capability in dealing with our wildfire problem. Failure now must either be borne by the fire managers, who now have the tools, or bring us to the realization that nature will not permit the next 1-2% to be bought except at absolutely unacceptable levels of public expenditure.

Never has a fire agency been offered the level of support to obtain its fire goals offered by our government and senior management. The ball is now in our court to manage this system to provide Alberta with a truly improved and effective cost-plus-loss record in the next decade that will allow renewed resource planning with confidence.

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OPERATIONAL RESEARCH APPROACHES TO FOREST FIRE INITIAL-ATTACK RESOURCE DEPLOYMENT ANALYSIS

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ABSTRACT

The focus of this paper is forest fire initial-attack resource deployment: the prepositioning of initial-attack resources in preparation for subsequent dispatch to fires. The author illustrates how operational research techniques can be used to enhance daily deployment analysis and describes some deployment research projects currently under way in Canada. The paper concludes with a brief discussion of the role that fire managers must play to ensure that they benefit from such research endeavors.

INTRODUCTION

The primary objective of a forest fire initial-attack system is to quickly contain potentially destructive wildfires that occur in forested areas. Because the damage and suppression costs that result from wildfires are heavily influenced by the response times of initial-attack resources, initial-attack dispatching is a very important aspect of fire management. The objective of initial-attack deployment analysis is to help fire managers decide how to preposition initial-attack resources so that initial-attack dispatchers are subsequently well prepared to dispatch them to wildfires that are reported.

Canadian fire managers must deploy complex mixtures of initial-attack resources (e.g., fire fighters equipped with hand tools and/or power pumping units, transport trucks and aircraft, and air tankers) on a daily basis. This important task is usually complicated by considerable uncertainty regarding the nature of the initial-attack fire load to be managed and the potential impact of suppression resources. It is therefore not surprising that they experience difficulties when they attempt to assess the potential consequences of deployment alternatives.

The purpose of this paper is to illustrate how fire managers can use Operational Research (OR) techniques to enhance their daily initial-attack resource deployment decision-making. I will begin with an illustration of how one OR tool (queueing theory) might be used to help resolve daily decisions concerning the number of helicopters to deploy for helitack transport purposes. I will then characterize the deployment task and briefly review previous attempts to use OR techniques to help resolve such problems. I will describe some current Canadian deployment-related research efforts and conclude with a discussion of the role of fire managers in such endeavors.

A SIMPLIFIED INITIAL-ATTACK RESOURCE DEPLOYMENT PROBLEM

Consider a hypothetical fire district where there are no roads and no air tankers, but an ample supply of fire fighters. Assume each fire that is reported must be attacked by a single five-person crew that must be transported to the fire by helicopter. Each afternoon the district fire manager must decide how many helicopters to charter for initial-attack transport (to fires) the following day.

Suppose the fire manager is uncertain how many fires will arrive (i.e., be reported) the next day, but he believes that a Poisson stochastic process with a constant mean arrival rate of 0.72 fires per hour can be used to model the fire arrival process. Similarly, he believes that the service time (i.e., the time required for a helicopter to transport a crew to a fire and return to its base) can be modeled as an exponential process with a mean service time of 1.25 hours per fire (i.e., a helicopter can service fires at an average rate of 0.80 fires per hour).

Suppose that a five-person helicopter can be chartered at a rate of $800 per day, regardless of the number of hours it actually flies. The fire manager is convinced that fire damage and suppression costs rise as response time increases, but he is unsure of the precise relationship between these factors. He is therefore willing to use expected fire waiting time (i.e., the average elapsed time from when a fire is reported until the transport helicopter leaves for the fire) as a surrogate measure of fire damage.

He wishes to evaluate his deployment alternatives (i.e., how many helicopters to charter each day) on the basis of helicopter costs and the expected initial-attack waiting time of fires.

Given the (admittedly gross) simplifying assumptions outlined above, queueing (i.e., waiting line) theory models can be used to provide the fire manager with information he could use to help resolve his decision-making problem. The system performance estimates presented in the table below were derived by using such a model (Wagner 1975, pp. 880–882).

Predicted daily helitack transport system performance

Number of helicopters chartered	Helicopter cost (dollars)	Expected fire waiting time (hours)
1	800	11.25
2	1600	0.32
3	2400	0.04
4	3200	0.01

DAILY FOREST FIRE INITIAL-ATTACK RESOURCE DEPLOYMENT

Fire managers must resolve deployment problems that are far more complicated than the simple illustrative example discussed above. Even if we restrict our attention to initial attack (and ignore fire servicing and extended-attack requirements), deployment poses many formidable decision-making problems. Some of the factors that must be included in "real world" initial-attack resource deployment analyses are as follows:

- the number of fires that may be reported in the near future (i.e., during the next 2-3 days), where they will be located, how they will behave, and what values they will threaten (i.e., fire load prediction);

- complex mixtures of suppression resources including fire fighters, mechanical equipment (e.g., bulldozers), and air tankers can be used for initial-attack purposes;

- complex mixtures of surface vehicles and aircraft can be used for initial-attack transport purposes;

- currently committed resources may be released from existing fires during the next 2-3 days;

- initial-attack weight requirements vary from fire to fire;

- initial-attack resource requirements (and the probability that a fire will not be controlled by the initial attack and thus become an extended attack fire) increase as response time increases;

- extended attack fires draw upon initial-attack resource supplies;

- fire managers must deploy initial-attack resources at many bases spread out over large (e.g., province-wide) areas;

- the performance of initial-attack suppression resources is difficult to predict, and the biological and economic impacts of fire are difficult to assess.

Given the magnitude of initial-attack resource deployment problems, it is clear that fire managers need all the help they can get. I believe that OR techniques can be of some assistance.

OR AND INITIAL-ATTACK RESOURCE DEPLOYMENT

OR (which is sometimes referred to as operations research or management science) entails the use of scientific methods to develop decision-making aids for managers. There have been numerous attempts (most of which are discussed in Martell (1982)) to apply OR to forest fire management problems. In this section I will briefly describe some of the OR efforts that have been focused on daily initial-attack resource deployment.

Greulich (1967) modeled the daily deployment of a small fleet of land-based air tankers to a small number of bases. He subsequently extended this work (Greulich 1976) to deal with home basing as well as daily transfer decision-making. Thompson (1968) and Martell (1972) explored ways of dealing with decisions concerning the number of initial-attack crews to place on standby at a base each day. Doan (1974) addressed the daily (and seasonal) deployment of initial-attack crews, transport aircraft, and air tankers at a single base and their subsequent dispatch to fires.

Potter and Minns (1973) and Vesprini and Brady (1974) explored ways of deploying line-building resources within a region on a daily basis. Hodgson and Newstead (1978) and Newstead (1980) developed models that could be used to help decide which (of a set of candidate) air tanker bases to operate. Bookbinder and Martell (1979) modeled the daily allocation of initial-attack transport helicopters to a number of bases within a region. Although these authors have furnished some insight into daily deployment decision-making problems, none of this research has truly been implemented.

Previous deployment research efforts suggest that daily initial-attack resource deployment decision-making is so complex that it may be impossible to develop tractable (i.e., solvable) comprehensive deployment models that simultaneously consider initial-attack crews, transport vehicles, and air tankers. It may be necessary to develop a small number of relatively simple models, each of which addresses a single class of initial-attack resources, and loosely couple them in such a way that fire managers can use the resulting aggregation of models to evaluate deployment alternatives. In any event, I believe it is possible to develop cost-effective decision support systems that fire managers can use to:

- predict fire occurrence, behavior, and impact 2 or 3 days in advance;
- keep track of the current status of fires and suppression resources;
- roughly evaluate daily initial-attack resource deployment alternatives in terms of costs and surrogate measures of fire damage.

CURRENT RESEARCH

Peter Kourtz of the Petawawa National Forestry Institute has for a number of years been working on the development and implementation of a comprehensive computer-based decision support system for regional fire managers. His system includes components that manage the massive amounts of data produced by modern weather data acquisition technology (e.g., lightning location, automatic remote weather stations, and precipitation radar), predict the occurrence and behavior of lightning and people-caused fires, and process suppression resource inventory management data. Field tests conducted in Quebec and Ontario indicate that his system produces valuable information that can be used to enhance daily initial-attack resource deployment decision-making.

At the University of Toronto, we are currently working on a number of daily deployment-related research projects. Darcie Booth is nearing completion of her M.Sc.F. thesis that deals with daily regional initial-attack crew requirements. She has developed a stochastic dynamic programming model that a regional fire manager could use to help decide how many initial-attack crews to bring into (or release from) his region each day. Her model considers the current status of crews within the region, and a 2- or 3-day forecast of new fire arrivals. She assumes the fire manager is able to assign a monetary value to the penalty cost that is incurred if a fire arrives when there are no initial-attack crews available for immediate dispatch. She has been able to derive optimal solutions to reasonable large problems, and has developed a computationally efficient heuristic procedure that produces "almost optimal" solutions to quite large problems. We hope to begin field testing her model in Ontario during the 1984 fire season.

Ms. Booth has also done a statistical analysis of some aspects of initial-attack system performance in Ontario's northern region. She examined data that indicate the magnitude of dispatch delays and how much time crews spend on various stages of suppression (e.g., the time from the start of attack until the fire is declared being held). She has also developed a preliminary version of a mathematical model that can be used to predict travel time (as a function of attack base to fire distance) for initial-attack crews dispatched by truck, which we hope to enhance with data collected by the OMNR's Northern Region staff during the 1983 fire season.

Tim Lynham, Sam Otukol, and I recently initiated a joint people-caused fire occurrence prediction research project, in cooperation with Brian Stocks of the Great Lakes Forest Research Centre and the staff of the Ontario Ministry of Natural Resources Aviation and Fire Management Centre. We expect to be able to develop improved methods of predicting daily and seasonal people-caused fire occurrence, and hope to have a preliminary prediction system available for field testing in Ontario during the 1984 fire season.

Julie Fortin has just begun work on her M.Sc.F. thesis, which will deal with the daily deployment of a provincial air tanker fleet. Although it is much too early to predict how generally applicable her model will be, I expect some of her results will eventually help to manage the deployment of air tankers on a national basis.

HARNESSING OR TECHNOLOGY

Forest fire managers will continue to be forced to enhance the productivity of decreasing amounts of increasingly costly resources to manage fire in forested areas that harbor increasingly valuable resources. OR has proven to be of considerable value to urban fire managers (see for example, Walker et al. (1979)). It's time we tackled daily forest fire initial-attack resource deployment in a concerted manner. The task will by no means be simple. In particular, such efforts are doomed to failure unless fire managers and OR analysts work very closely together under the direction of a high-ranking line manager within the fire organization. Some of the many activities that fire managers will have to be deeply involved with include:

- investing substantial amounts of money in computer hardware, software, associated communications facilities, and specialized support staff to develop and maintain these resources;
- conducting field studies to investigate the cost-effectiveness of suppression resources (fire reports alone will not suffice);
- system specification and model development (you cannot leave OR analysts in "ivory towers" and expect them to develop cost-effective decision-making aids for real problems);
- detailed field testing of the decision-making aids that are developed (over extended periods of time);
- dealing with important interactions between decision support technology, organizational structure, and management practices.

If fire managers choose to use modern decision support technology to enhance their daily initial-attack resource deployment decision-making, they must devote substantial amounts of time and money to the task, and they must work very closely with the OR analysts and researchers involved to ensure that cost-effective decision-making aids are developed.

ACKNOWLEDGMENTS

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MANAGING LARGE FIRES IN THE NORTHWEST TERRITORIES

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INTRODUCTION

The Northwest Territories of Canada is a large, vast area. One-third of the land mass of Canada can be found in the Northwest Territories (3 379 686 km²).

Much of this area is not treed, consisting of tundra with low-growing forms of vegetation. There are approximately 1 366 000 km² of forested land within the tree line. This natural division follows a line southeast from the Mackenzie River Delta to northern Manitoba. The forest contains typical boreal species such as white spruce, black spruce, birch, poplar, and jack pine.

Physiographic regions range from typical Pre-Cambrian Shield in the east through the Interior Plains to the Mackenzie Mountains and the Continental Divide in the west. Topography in the east, on the Shield, consists of rolling hills, drumlins, moraines, and rock outcrops interlaced with a myriad of small and large lakes. The Mackenzie Lowlands are generally flat on clay, sand, and silt deposits. Vegetative cover consists of grass meadows to large stands of pure black spruce, white spruce, and jack pine. The Mackenzie Mountains are a continuation of the Rocky Mountains with deep river valleys and extensive stands of spruce with tundra toward mountain tops.

Within the tree line, population is found primarily around Great Slave Lake, the Slave River valley, the Liard River valley, and the Mackenzie River valley to the arctic coast. Population total in this area is about 25 000 people. Forest fire management efforts are concentrated in this area.

FIRE HISTORY

Fire history in this area is typical of other boreal forested areas. Large stands of single species, a dry climate, and the occurrence of lightning tend to favor the growth of large fires. It has been estimated that fire has visited every square mile of the area at least 100 times since the departure of the last ice age 10 000 years ago.

In the past 5 years, from 1979 to 1983, approximately 5 million acres of land have been visited by fire. Individual fire sizes have on occasion exceeded 500 000 hectares.

FIRE MANAGEMENT POLICY

In this environment, the Department of Indian and Northern Affairs (DIAND) has developed and implemented a policy of protected and nonprotected areas. A total of 266 760 km² is included in the Fire Attack Zone, or protected area. The Observation Zone, or nonprotected area, includes the remaining land within the tree line. The Fire Attack Zone contains areas that are of significant value based on human life and property, timber, hunting and trapping, watershed, and recreation. The Observation Zone covers areas that are considered of least value and are utilized less by people.

Land areas that are to be included in one or the other of the zones are determined by a process of public consultation. The limits set by policy for the size of the total protected area and fire fighting resources are considered in the process.

This policy was recommended by the 1979 Fire Review Panel appointed by the DIAND Minister and chaired by Peter J. Murphy of the Forest Science Department at the University of Alberta.

INITIAL ATTACK

In the Fire Attack Zone, initial attack is usually made with helicopter-borne five-man crews. DC-6B air tankers are used on approximately 30% of all fought fires occurring in the Fire Attack Zone in the initial attack phase. Resource levels for initial attack are being set to coincide with values in the Canadian Forest Fire Danger Rating System. This supports the concept of acquiring and placing resources before actual fire occurrences to provide a strong, aggressive attack force.

Inevitably initial-attack resources in multiple-fire situations are expended or fire weather is such that fires do escape initial attack in the Fire Attack Zone. Fires in the Observation Zone occasionally threaten or encroach on the Fire Attack Zone. At this time we are usually faced with a large escaped fire or several large escaped fires.

STRATEGY ON ESCAPED FIRES

The overall strategy of an escaped fire is determined by reference to policy (that is, what zone it is in), consideration of the values that are at risk or threatened, spread potential, resources that are available, and current and predicted immediate future fire weather.

Through analysis of the above items, a decision is made to attack the fire by full suppression or limited action. Full suppression would be used when a fire in the Fire Attack Zone threatens high values, for example a community. Limited action could be used when a fire is isolated from high values in the Fire Attack Zone or when a fire encroaches on the Fire Attack Zone from the Observation Zone. In the latter case, fire action may be limited to the portion of the fire that is actually in the Fire Attack Zone.

During periods of multiple fire occurrence in the Fire Attack Zone, the immediate strategy may be to allow a fire to continue spreading until resources are available. This is termed delayed attack. This delay may be as little as an hour from report of the fire to a number of days. No fire action may also be a valid strategy should the fire occur in an older burn or on an island.

Fires that occur in the Observation Zone are normally not actioned. This strategy has been determined by policy. Policy does, however, allow flexibility to deal with small zone boundary fires or fires that threaten life and property.

If a decision has been made to fight a large fire within the Fire Attack Zone, the practice is to designate a group of persons as an overhead team and allow them to continue action on the fire. An overhead team consists of three main positions: a fire boss, a line boss, and a service chief. Other positions are appointed as the situation demands. These can include air personnel, special ground supervisors, a fire behavior specialist, public affairs officers, and an emergency measures liaison.

TACTICS ON ESCAPED FIRES

The tactics used on large fires are the responsibility of the overhead team, particularly the fire boss, and are a result of its planning and estimation of fire behavior.

Fire that are in the Fire Attack Zone and have been given the overall strategy of full suppression are fought with varying tactics depending largely on accessibility, terrain, fuel types, fire weather, and availability of water.

In more southern protected areas, bulldozers are available and in some years the swamps are dry enough to utilize them. Burning out is then conducted unless direct attack was used. Power pumps and hoses, however, are the mainstay of our ground attack. Usually five-man crews suppress fire by directly utilizing this type of equipment. This is particularly true in areas where ground access by heavy equipment is impossible.

Helicopter support for bucketing and deployment of ground crews is essential for the type of tactics most used and the inaccessibility of most fires from roads. Aerial application of retardant to the forest cover along seismic lines and subsequent burning out of fuels by aerial ignition has also worked well as a tactic.

Consideration of the use of natural barriers is also given high priority in making tactical decisions, as their use can reduce the amount of fire line that needs to be built and held. This reduces resource requirements for the particular fire, making the resources available for initial attack.

The use of explosives for line construction and for creating small water bodies to pump water from swamp areas has also been used with good success.

Tactics on fires that are to receive limited action would be very similar to those used on full-suppression fires. Because the decision was one of limited action, however, this implies limited resource allotment to the fire by virtue of the fire being isolated from values encroaching on the Fire Attack Zone only or by the existence of multiple fires. There is therefore a tendency for fire managers to choose a tactic that utilizes fewer resources, such as burning out from natural barriers, hot-spotting fire areas that have significant spread potential, using direct or indirect attack close to high values (cabins, lodges, etc.), or allowing a fire to spread to an area where there is little or no fuel, for example a mountain top.

FUTURE DEVELOPMENTS

The concept of the fire management zones will continue well into the future. The economics of total fire exclusion from a financial as well as an ecological point of view demand this.

Implementation and refinement of the many decision-making aids that are becoming increasingly available and use of computer programs for data analysis will assist the fire manager in decision-making in this environment.

SUMMARY

- In a large area with small population and a forest prone to occurrence of large fires, a policy of protected and nonprotected areas has evolved.

- Initial attack capability is provided in the Fire Attack Zone, while fires occurring in the Observation Zone are normally not fought.

- Strategy on fires that escape initial attack is related to policy and individual fire analysis. Overall strategy may consist of full suppression, limited suppression, delayed attack, or no action.

- Tactics utilized on escaped fires are the responsibility of the overhead team. Varying tactics are used depending on accessibility, terrain, fuel types, fire weather, and availability of water.

- The concept of fire management zones is expected to be utilized well into the future. The increasing availability of modern technology will serve to enhance this concept.

MANAGING LARGE FIRES IN ALASKA

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INTRODUCTION

Any discussion about wildland fire management in Alaska must first be set in its true perspective. This perspective relates not only to the size of the land mass and its inherent fire regimes, but also to the evolution of the protection programs and organizations, including fiscal, political, and biological influences. The following general discussion is provided to define the fire management problem in Alaska, with emphasis on large fire management.

GEOGRAPHIC FEATURES

Within Alaska's 375 million acres, approximately 220 million acres are considered to be subject to fire. The fire-prone area exists largely between the Brooks Range in the north and the Alaska Range in the south. Although the state has some very prominent mountain ranges, fire in high elevations is not a problem due to the lack of vegetation above 3000 feet. The major influence of the mountains on fire is their climatic effect on marine air, rain shadows, and winds.

A variety of climatic zones can be found across the state, ranging from coastal marine and cool arctic regions to the exceptionally warm and dry interior, which experiences heavy lightning activity throughout the summer.

The vegetative pattern is diverse and varies by climatic region. In the moist southeastern panhandle a dense Sitka spruce forest is found. The arctic north slope and western coastal areas are predominantly moist tundra and muskeg. The interior region contains upland and lowland white spruce-hardwood forest with bottom land black spruce, tundra, and muskeg interspersed in the poorly drained areas.

Alaska's total population is approximately 465 000. The largest populated area is Anchorage with approximately 200 000 permanent residents. Population increases greatly in the summer months with densities found along the road net and rail belt located in the south-central portion of the state. Hundreds of villages are scattered across the state and are located in remote areas accessible only by air or water travel.

THE WILDFIRE PROBLEM

Wildfire has historically been a major modifier of the environment in Alaska by playing a major role in vegetative diversification and animal habitat. It is estimated that prior to any suppression efforts 1.4–2.4 million acres burned annually. As the population increased, so did the number of man-caused fires. Today, well over 600 fires occur annually, with man-caused fires accounting for up to 65% of the total in some years.

Fire occurrence and behavior vary by geographic region, with the following regional characteristics:

Southeast Alaska: Fires are primarily man-caused, fewer than five per year. Normally they burn with moderate to low intensity.

Arctic and coastal: Lightning is rare but occasional ignition will occur. Low man-caused occurrence. Burning intensity is moderate to low.

South-central: High number of fire incidents annually, with 65% man-caused. Intensity is moderate to extreme depending on weather factors. Resistance to control is moderate to high with the urban interface of the population a major suppression concern.

Interior: High lightning occurrence throughout the area with incidental man-caused occurrence. Intensity is moderate to extreme with resistance to control moderate to extreme. Area accessible only by air.

ORGANIZATION AND PROTECTION PROGRAM DEVELOPMENT

The evolution of fire protection in Alaska strictly parallels the conceptual impact fire has created on man's activities. Only in very recent times has fire been viewed as having a positive effect to a level that influenced the suppression response for anything but total suppression.

The first suppression effort was generated during the construction of the Alaska Railroad in 1915–23. Although previously recognized as destroying the forested land on a large scale, it was fire in the vicinity of man's activities that produced action. In 1916 the U.S. Forest Service expanded its fire protection plans to include interior Alaska, but the responsibility was finally given to the General Land Office (GLO), which initiated the first prevention effort in 1921 and established patrol of the railroad from Seward to Fairbanks from 1929 to 1933.

With its responsibility to supervise the Civilian Conservation Corps (CCC), the GLO utilized that manpower normally to suppress fires threatening areas where airport and site construction was being accomplished. As the CCC dropped out, the military became concerned that the smoke from the many large fires in the state compromised its defense requirements. The military subsequently provided substantial fire suppression support to the Alaska Fire Control Service (AFCS), which was established in 1939. With an annual budget of $37 500, the AFCS only looked at fires along rivers and roads. In 1946 the AFCS was absorbed by the Bureau of Land Management (BLM). The BLM expanded its organizational capability and areas of protection into the interior in 1950, and established a smoke jumper base in Fairbanks in 1959.

Statewide protection coverage was achieved in the 1960s through reimbursable agreements, and technology advanced significantly. At this time, the objective was to suppress every fire.

For the first time, in the 1970s, ecological concerns associated with fire suppression were implemented. The BLM adopted a procedure to allocate suppression forces based on values-at-risk, fire danger ratings, and prior commitments to going fires. Coinciding with this was an assessment of fire impact on escaped fires. The ability to modify procedurally the full attack requirement was achieved.

The redistribution of land to other ownership required the State of Alaska to assume fire protection responsibility on state and private lands, and the new suppression organization assumed its first responsibility in 1973. A progressive schedule for expanding the state suppression organization and protection area is continuing, and a comprehensive cooperative protection agreement between the state and the BLM is in effect and remains essential to statewide protection. To date the state's Department of Natural Resources, Division of Forestry, protects 58 million acres of mixed-ownership land. By 1985 the acres protected by the BLM and the state will balance with the Division of Forestry protecting the southern half of the state and the BLM the northern half. The program now requires sharing of a major responsibility and a significant effort has been made to identify total force requirements. Each agency is supplying its share of the total need with extensive efforts made to prevent duplication.

MANAGING LARGE FIRES IN ALASKA

The single most-effective means to reduce the large fire problem in Alaska is to maintain a highly mobile and effective initial-attack capability. The size of the state makes it impractical to maintain a work force that would be stationed throughout the fire occurrence areas in sufficient numbers to attack all fires in a particular area. Therefore, the total mobility concept requires mobilization of attack forces from one area to another with a rapid recovery capability. In addition, cooperative agreements provide for total utilization of other agency suppression forces. Initial-attack forces in Alaska are comprised of smoke jumpers, helitack, ground tankers, and air tankers.

To expedite the initial-attack effort in time for it to be effective, a dependable, real-time detection system is required. The Division of Forestry and the BLM utilize an automated lightning detection system with sensors located throughout the lightning belt. The data are delivered in real time to the various field stations, which deploy aerial detection directly to the area where lightning occurs. This process has increased detection effectiveness as well as reduced the number of dedicated aircraft, flight hours, and associated costs.

Even with an effective initial-attack organization, some fires escape and reach a considerably large size, ranging from a few thousand acres to over 300 000 acres in some cases. This occurs primarily when the number of fires exceeds initial-attack capability over a number of days or when fire behavior prohibits direct attack.

In Alaska today, there is a substantial difference between a "large fire" and what is viewed as a "problem fire". Some fires reach a large size, but because of fuel types, available natural barriers, and low resource priority, they do not receive a large suppression commitment. Others are recognized as "problem fires" due to location in high-value areas, extreme fire behavior and potential, and lack of sound suppression alternatives. Suppression force commitment can exceed 500 people and cost well into the millions of dollars to suppress, but be applied to areas of only 10 000 acres or less.

INTERAGENCY FIRE MANAGEMENT PLANS, A DEPARTURE FROM TRADITION

Probably the most significant change in large-fire management in Alaska has been a major change in identification of protection requirements and a resultant policy shift.

The long-standing policy to attack every fire and continue attack until it is suppressed has accounted for suppression expenditures into the millions of dollars every year. Several factors have occurred to mandate change, and an entirely new concept is being adopted statewide in Alaska with interagency participation, called **Interagency Fire Management Plans.** This planning effort was initiated primarily when the land changed ownership on a large scale. Statehood entitled the state to 104 million acres of land. The Alaska Native Claims Settlement Act (ANCSA) transferred 44 million acres of land to native ownership. In addition, the Alaska National Interest Lands Act (ANILCA) distributed the management stewardship for 195 million acres within the Department of Interior among three agencies: Bureau of Land Management (75 000 000 acres), Fish and Wildlife Service (77 000 000 acres), and National Park Service (43 000 000 acres)

With new land managers and owners came a new outlook on fire suppression, and not all opinions were in agreement. A prime consideration was the absence of site-specific resource management plans, which would normally define the fire activity plans for suppression and management. Therefore, fire and resource managers have concluded the following:

1. The overall costs associated with suppressing **all** fires in Alaska have reached the point where they must be reduced. Some fires do not adversely affect the natural resource base. In some cases, the damage resulting from suppression activities is more detrimental than the fire itself, especially where catlines are constructed in permafrost areas.

2. In its natural role in the Alaska environment, fire provides for large-scale decomposition and short-term nutrient recycling. In the subarctic conditions no other natural decomposition occurs within a short time span. This enhances vegetation regeneration and diversification.

3. The wildlife in Alaska will continue its important role in the state's economy. The use of fire to improve wildlife habitat is the most economical method of achieving the wildlife management objectives.

4. Interim to the development of site-specific resource management plans, some broad-scale resource management objectives can be achieved through better fire planning while reducing the overall cost of suppression.

Through this process, land managers and owners joined with fire management representatives to establish four levels of protection standards or management options for land classification.

Critical: Life and property sites that receive rapid and aggressive suppression.

Full: Areas of high-value resources where fire adversely affects the resource management objective. Attack is aggressive with an effort to extinguish the fire immediately.

Modified: Areas of high-value resources but where the alternative exists to trade acres burned for suppression cost. Initial attack is immediate but resource managers guide the suppression effort.

Limited: Areas where wildfire is not having an adverse impact and no suppression action is taken except to prevent fire from burning on to higher-value land.

To date 154 million acres have been identified under the planning concept with the following number of acres per protection level:

Critical: (Site-specific, not tabulated)

Full: 38.1 million acres

Modified: 33.6 million acres

Limited: 82.6 million acres

Total: 154.3 million acres

Only 50% of the fire-prone area has been reviewed under this process, but the resulting benefits have started to prove themselves. These benefits include the following:

1. Reduction in suppression cost in modified and limited protection areas. (Over $1 million that normally would have been spent on suppression was saved on one single fire in 1983.)
2. The suppression organizations are able to rank the importance of attack force commitments during multiple fire occurrence.
3. The available suppression forces are now utilized in the most important areas.
4. Resource management objectives benefit where fire is desired, as in the case of moose habitat.
5. Consensus of the suppression action necessary for various parcels of land is attained among land managers.

This new concept does not come without concerns and problems. To be effective, the concept must be implemented by the suppression organization and achievable at all levels throughout the organization. The following concerns have arisen:

1. The information and data displays are cumbersome when presented in map and book form. In some planning areas, over 300 one-inch-to-the-mile quad maps are required. Also, significant staff time must be devoted to produce just the software after protection level determination is made. In order to overcome this problem the BLM, in cooperation with the State of Alaska, is installing an automated initial-attack information system that will display the land status and protection standard for any given location. The system will be operational in 1984 and by 1985 will display lightning data, fire behavior data, and weather data in addition to status.
2. A dependable, real-time communication capability between the field suppression office and the responsible land manager is required when fires in limited or modified protection areas require commitment decisions.
3. Fires in 'limited' areas require monitoring and confinement. This is a workload in the suppression organization that has not been fully evaluated. Cost of confining fires may exceed the cost of initial attack when evaluated over a period of years.
4. With conceptual planning done on such a broad-scale basis, accuracy in resource value assessment is continually in question and adjustments will go on for many years.
5. A limited-action fire receiving no attack leaves an uncertain liability issue if the fire burns onto other ownership.
6. A high number of large fires could occur in low-priority areas, producing heavy smoke and therefore adversely affecting detection, attack, and support to fires in higher-priority areas.
7. With the dynamic changes occurring in Alaska, an annual update of the fire plans is required, resulting in a continuous but decreasing workload.

It is quite important to realize that this product does not **replace** intensive resource management plans but serves as an **interim guide** for fire suppression action until comprehensive resource management plans are developed. As the individual resource management plans are completed, their requirements will supersede the fire plan and will be incorporated in suppression activities. A copy of the Fire Management Plan Guidelines is provided as a handout at this session.

TACTICS AND SPECIALIZED SYSTEMS

Large fires in Alaska require use of a variety of tactics and support systems, depending on location and the suppression priority for each fire.

The fires demanding the highest level of management and concentrated effort are those burning in heavy spruce forests and located near population centers. They typically have road access permitting use of heavy equipment where the suppression priority and the impact on the environment allow. Strategy and tactics are quite straightforward and try to contain the fire to the smallest possible area.

In more-remote areas, the tactics utilized are quite different. If the airborne initial attack fails, an escaped-fire analysis is completed that reflects suppression alternatives with associated costs weighed against resource damage or potential loss. Where reasonable, natural barriers are utilized for control lines. Burning out is the primary tactic along the natural barriers, using aerial firing fusee dispensers as the primary tool. Ground forces are deployed for holding and mop-up. The objective is to contain the fire on a basis of suppression cost plus resource loss efficiency. Only the least amount of personnel and equipment required is assigned to help reduce the expensive effort of suppression and support to the remote area fires. Conventional techniques are employed for support, including paracargo and helicopter delivery.

The BLM has developed and made operational a Fire Line Explosives (FLE) capability. The FLE is utilized where line construction is desired between natural barriers for burning out. The explosives are effective in brush and tundra and leave a line that is sufficient to hold a typical burn-out fire. The FLE is deployed by smoke jumpers using eight people, and an average of 1500 ft. of fire line can be constructed in 1 hour. The FLE is expensive ($3.15 per foot), and to be dependable an on-hand inventory of 50 000 ft. is required. It is cost-effective whenever line construction must be accomplished within limited time constraints to meet control objectives. A report on this process is available from the Bureau of Land Management, Alaska State Office.

Fire overhead and line crews must be available to suppress large fires successfully. In Alaska significant interagency use of overhead is necessary during heavy fire years, and training and qualifications currently meet the National Interagency Fire Qualifications System. Both federal and state suppression agencies have recognized the value of adopting the National Interagency Incident Management System and plan to convert to it in 1986.

To provide the large line-crew work force necessary, residents of native villages are formally trained and organized. This has been a successful program providing an on-call labor source across the state. With most villages accessible by aircraft, rapid mobilization can occur and the crews are committed to assignment for up to 21 days.

Another advancement in large-fire management was the development of the Natural Resource Officer (NRO) position on the overhead teams. The suppression forces have long been hampered without a readily available resource management representative dedicated to the project fires. This resulted in delayed decisions or best-guess approaches for resource and environmental considerations in the suppression plans. Resource-knowledgeable people were provided technical fire training and placed in the plan function to assure that suppression strategy and tactics are compatible with environmental concerns. Normally the individual assigned is familiar with the local area and the resource inventory and management objectives. The NRO directly applies these considerations daily to the strategy and tactical plans.

MANAGEMENT ROLE IN MULTIPLE LARGE FIRES

As indicated previously, ownership and management of the land are distributed among several agencies. Suppression organizations utilize cooperative and mutual aid agreements to move forces in sufficient quantity to wherever a problem exists. Likewise, management representatives from the various agencies combine into a command group to make statewide priority decisions when fire occurrence substantially exceeds their combined in-state or support capability. Agreement is reached for where suppression forces are to be assigned. Adjustments in initial-attack commitment are often made, from reducing the number of smoke jumpers on an individual aircraft to the identification of blocks of land where no commitment will be made at all.

SUMMARY

In conclusion, the Alaska suppression program is attempting to change its posture commensurate with land management requirements and economic constraints. Innovation and departure from traditional suppression methods are clear objectives necessary to achieve a cost-effective and balanced program. The sensitive Alaska environment prohibits the use of heavy equipment for line construction, and acres are often sacrificed for time and use of natural barriers to secure containment of the fires. The merging of resource managers and technical fire personnel has greatly reduced the land area that requires priority suppression commitment, although the full impact of free-burning fires will not be known for some time. As fire technology and the understanding of the Alaska environment advance, more dramatic changes in the role of fire and the resultant protection programs can be expected.

MANAGING LARGE FIRES IN BRITISH COLUMBIA

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INTRODUCTION

In talking to a group of dedicated forest fire experts, it may be somewhat obvious when I make the point that in British Columbia, as elsewhere, our fire suppression organization is continually changing and adapting. Our minimum objective remains to control all wildfires by 10:00 a.m. of the day following discovery. Unfortunately we never attain the ideal, but target objectives must be maintained to test and improve an organization.

To set the stage for British Columbia, just a few figures:

- most expensive year: 1982 — $42 million, burning 340 000 ha
- most hectares burned in one year: 1958 — 830 000 ha
- the largest single fire: 1956 — covered 250 000 ha
- our 5-year average is 2500 fires and 114 000 ha
- this year we are projecting 1600 fires, covering 80 000 ha and a cost of $25 million.

This year most fires were contained within the first burning period and at a small size. The largest fire was early in the season and occurred in the northern part of the province. The Swiss Fire, near Houston, covered 18 000 ha. I'll talk about this Swiss Fire in detail later.

POLICY

Under the Ministry of Forests Act and the Forests Act, the ministry has jurisdiction over the control of all forest fires in the province. The broad objective in the control of forest fires is to keep cost and damage to a minimum. The working objective is that all fires are to be contained by 10:00 a.m. of the day following discovery; that is, prior to the start of the next burning period. The action that can be taken is the responsibility of the district manager, who is experienced and can evaluate the local conditions and circumstances.

The responsibility for fire control starts at the district level. Within the six forest regions in British Columbia, there are 46 districts. Throughout the fire season, the districts are prepared for any fire, with crews standing by ready for action. When a fire is not brought under control, working to the 10:00 a.m. concept, a reassessment is made to determine the action required to attempt control by 10:00 a.m. the next day if possible. The district keeps in close touch with regional headquarters. While a fire may not be under control, it may not be a problem. A review has to include the values at stake.

In managing large fires, we have three basic options:

1. No action. This is when early detection or initial attack has failed. In the north we have had large rolling fires with little or no forest timber values at risk. The fire is kept under observation. Depending on various factors, such as the weather or a change in wind direction, our management decision may be changed. In the far north, groups of fires have been kept under observation for many weeks until rains put them out.
2. Limited action. A large fire may warrant limited action for a period of time. A large running crown fire may prevent us from taking all the action we plan to do. There may be priorities, such as evacuation and saving property, or other values needing full action while other areas of the fire are kept under observation. Limited action may develop into full action or, as the fire changes because of conditions or weather, there may be no further action.
3. Full action. We may have had failure with initial attack but because of high forest values at risk as well as property and life, then everything possible has to be done.

The decision-making process, however, in selecting one of the three options is fraught with pitfalls. This can range from a forester considering caribou habitat of limited value to the full-blown political implications that can occur when a manager makes these critical decisions in isolation.

Recognizing the importance of this process and the direction in which our forest fire suppression costs were heading, our ministry has established an uncontrolled fire attack planning process. Like all good bureaucratic processes, this developed an acronym: UFAP. The procedure basically deals with wildfires where initial attack has failed and early follow-up action is not successful. The objective of this procedure is to determine an appropriate level of fire suppression action that is efficient and effective consistent with values at risk. Instead of leaving the entire action decision to the district manager, the new procedure involves the district manager, regional manager, and, in many cases, Victoria Headquarters.

Instead of final accountability for no action, limited action, or full-scale attack falling solely on a single district manager, he can now be supported by the region and headquarters. This factor becomes extremely important when raging wildfire can destroy valuable private properties and perhaps involve loss of lives. The fact that the action decision was supported by a group of experts rather than a single individual is important.

WILDFIRE MANAGEMENT

Our basic large fire control organization consists of the functions of command, operations, and support. Although usually associated with the control of large fires, it is recognized that these functions are equally valid and necessary in the control of small fires. I will not dwell on the control organizations of major fires in any detail as they are more or less universal with some slight modifications. These involve positions such as fire boss, line boss, equipment boss, air operations officer, and administrative officer.

The responsibility for fire control, as mentioned previously, starts at the district level. The district manager, as head of the district command function, must be prepared to assign responsibility and delegate authority to his district duty officer and other competent people in his district. On small fires, whoever leads the first attack takes responsibility for command, operations, and support. If the fire is held and suppressed quickly, the organization, with a few people, may remain at that level. Larger or project fires require an expansion of the basic fire organization into a more complex structure.

The extent of suppression resources required depends on the size and composition of the attack force and the expected duration of the fire. Direct control over all major fire suppression operations is assumed by the district command group. The group can request extra help and equipment from the regional forest fire control center. The regional duty officer in turn can call on the provincial forest fire control center in Victoria for assistance. It is also understood that if our resources are strained to the limit, we can now tap the Canadian Interagency Fire Centre for additional assistance.

The location or size of the command group is not fixed. The forest region, ministry headquarters, and industrial personnel usually become part of the command group as circumstances dictate. This can strengthen the group's ability to make managerial plans and decisions during a period of heavy fire load, and also relieve the key district staff, if necessary, for other pressing duties such as initial attack on other fires and support roles. The command group concept is flexible. Within the basic structure, support staff are added as required.

A public relations officer is usually responsible for all media relations on one or more fires as directed by the district representative. He reports to the district manager. This position is becoming increasingly important with today's mobility and aggressiveness of the news media. For example, we are aware that one major television network constantly monitors our ministry radios.

THE SWISS FIRE

I would now like to give you a brief case history of the Swiss Fire that took place in 1983. Two visitors were smoking fish. Their plastic and wooden smokehouse set overhanging trees on fire, and within minutes the fire was moving fast through spruce and balsam and spotting. The fire ultimately covered 18 000 ha, burned seven houses plus outbuildings, and cost several million dollars in fire-fighting and damage costs.

The fire started in the Morice District, which is in the Prince Rupert Forest Region. The area, approximately 28 km from the town of Houston, is a nonsupervised recreation site used by local fishermen.

The day was May 29, 1983; the time, 14:23. It is interesting to note that we had somewhat unexpected weather in that time, with record-breaking maximum temperatures and extremely low humidities. The temperature, 35°C, was 20 degrees above the normal for May. An Atmospheric Environment Service weather technician commented: "None of the forecast outlooks accurately predicted the extreme conditions which occurred on the 29th and 30th". The local tourist information center was not open and there were no forest restriction orders on campfires or travel. Fire prevention messages in print and on radio were a continuing part of a high-profile campaign by the region. A similar provincially sponsored campaign on television and radio had not started.

A brief summary of the action follows:

- Within 3 minutes of the fire starting, it was confirmed by a lookout 24 km away.
- Eleven minutes from ignition, a bird dog confirmed the fire, already covering 6 ha, moving fast and spotting. He recommended tanker action.
- A Zenith 5555 call by a resident in nearby Buck Flats reported smoke.
- At 23 minutes from ignition, a tanker drop was completed but the fire size was now 40 ha.
- Three minutes later, the bird dog reported the fire was now 60 ha and building; further tanker action would have no effect.
- Another 5 minutes. Bird dog reported the fire was now 100 ha and spotting ahead into a large plantation.
- At 15:56 an initial-attack crew arrived at the fire. The size was now 120 ha and beyond initial attack.
- It was immediately recognized by district and region that this fire threatened millions of dollars of property value in the Houston area and billions of dollars of timber values. A full-scale attack was necessary.
- Within an hour, 10 cats, a medium helicopter, and one retardant unit had been mobilized together with 100 men.
- The request was made for an "overhead" team to provide supervision commencing May 30 (the next day). A call was made to one ranch house, the occupant was warned, and the Provincial Emergency Program regional manager was contacted.
- Around 17:00 a recce by forest and industry personnel showed the fire size was approximately 200 ha. At this time the objective was to contain the fire at its present size and the strategy was direct attack. Cats started building a line along the east flank. The temperature was still 28°C, relative humidity 28%, and the wind east at 15 kmh.
- Between the 17:00 recce and 21:00, the fire crossed plantations on the west and flared into 35-m merchantable timber. The fire front was spreading east to west at 1½–3 kmh and spotting.
- At 22:00 the fire was approximately 6900 ha. The objective then became the development of a larger and more complex attack plan by 05:00 on May 30, and to cut off public access to the fire area to ensure there was no loss of life.
- Tactics included a recce flight by the district command group and overhead team at 04:30 to determine the fire boundary.

At this point, the plan included two 200-men camps, a fire control center separate from the district office, and rapid buildup of equipment, including six helicopters.

- The next day, May 30, was very tough. Due to a wind shift, the northern flank created the previous day became the front, approximately 18 km long. During the day, the fire increased from 7000 to 18 000 ha and seven homes and various buildings were lost, but there was no loss of life. At 16:00 the temperature was 35°C, the humidity 15%, and the wind northeast at 15 kmh.
- Based on fire behavior and weather forecasts, the command group expected extreme fire behavior, but it was not possible to determine the direction and extent of spread.

The objectives of our plan at this point were to preserve life and property, to hold the fire at north and east sides at present location, mobilize forces and commence establishing control lines on other flanks, and for men and equipment to continue to gain control in various sectors where this was possible.

- At 13:00 air tankers were requested to assist in holding the east flank but turned to another target when the "magnitude of the situation became apparent". The fire was spreading over the entire perimeter, torching and crowning in some areas.
- At 14:45 crews on the eastern flanks pulled back. Then, on the west flank, the Buck Flats residents were alerted to the danger.
- Back-burning was started from roads east of the fire in an attempt to keep the fire from running over the ridge and into Buck Flats.
- By 17:00 the new objective was to protect human life. Twenty minutes later the PEP people and the RCMP

commenced evacuation of the Buck Flats residents. All fighting forces and equipment were ordered to pull back.

- At 22:00 the fire had spread to 16 000 ha, all lines were lost, and 50 families had been evacuated. The north flank of the fire was approximately 18 km long, 12 km south of the town of Houston and moving at about half a kilometre an hour.

The main problems that day were as follows:

- All lines were lost and seven homes and other buildings were lost.
- Suitable river crossings could not be located.
- PEP and RCMP had some problems enforcing evacuation and keeping people out of Buck Flats.
- Burn off on the east flank was not effective.
- Camp establishment was delayed when fire threatened to overrun the location.
- Press coverage, heavy smoke, and general activity created great concern by residents in the Houston area. There was considerable public and media pressure on the district staff.
- On Tuesday, May 31, the weather changed for the better. At 16:00, the temperature was 9°C lower at 26°C, and the humidity up from 15 to 39%. Good progress was made in containment.
- On June 1 the number of men on the fire was 421. From that day onwards, the weather continued to cooperate.
- On June 4 the work force reached 631. (There were 44 crawler tractors, 43 skidders, and 3 medium and 8 light helicopters.) Control was achieved and never lost.

On this fire, a predetermined district command group plan was very rapidly implemented under the direction of the district manager. On May 29th, it was obvious that an Uncontrolled Fire Attack Plan (UFAP) was necessary and therefore implemented. Regional Protection staff were at the scene within hours, assisting the district manager in control efforts. Following the UFAP plan, personnel from Victoria became a part of the decision-making process, providing advice and assistance and endorsing the action taken. In my opinion, the combination of rapid implementation of the district command group plan followed by UFAP assisted in relatively rapid control with no loss of life under the most adverse possible conditions. It must be emphasized that the majority of the damage happened in a 48-h period.

After all large major fires in British Columbia a review board examines all facets of each fire action to determine strengths or weaknesses of action and where improvements can be made. This review board may involve the general public and industry through an interview process. This review or audit process is essential to improving our management of major fires.

The volatility of the Swiss Fire is only a warning sign of the future. As access improves and people persist in living in a rural environment, the responsibilities we face as managers of project fires will increase accordingly. We will have more and more nontimber values as well as timber values to protect. Management decisions must be instantaneous.

Obviously, the best management tool available to reduce costs and damage of large fires will continue to be to prevent them. More of our effort and resources must be channelled into this area.

In the meantime, our current philosophy is a joint management action decision-making process on fires that have not been contained at initial attack to establish:

1. no action;
2. limited action; or
3. full action; and
4. review and audit process.

LARGE FIRE MANAGEMENT IN ONTARIO

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You have no doubt heard at one time or another the lead line, "A funny thing happened to me on my way here". In my case the situation was not funny, but it otherwise perhaps fits as a case study addressing our topic of large fire management in Ontario.

On September 3 and 4 the northwest region of our province experienced an untypical late-season outburst of project fires that burned approximately 400 000 hectares in those 2 days. This resulted from about 25 fires scattered through the north but with special emphasis on 10–12 fires threatening special values.

This event touched off a large-scale organization and mobilization of resources involving all facets of our ministry, the wood industry, and native communities, which I would like to use as a scenario for our discussions. I will set it out chronologically to assist in developing a better feel for the process.

Previous to 1982, the province was officially divided into the following three zones for protection purposes:

Intensive Protection Zone — South of 52°30′ in the forest area was considered Fire Exclusion;

North of 52°30′ to 54°00′ — a zone of limited action to protect private property or other significant values as required;

North of 52°00′ and in southern Ontario — an area not mandated to wildfire protection, but dealt with as either a clear exception or as a mutual aid process to municipalities.

In 1982 a new policy was approved that established a means to recognize fire as a natural force and to select strategies other than fire exclusion if appropriate for the province south of 54°00′.

Approaching September 3 this year, the use of escaped fire analysis techniques had created a soft boundary across the north at about 52° where to the north, several fires had been contained by small forces, several others were initial-attacked and suppressed, and others were simply being observed periodically to determine their possible effect on values. Similarly, south of this line more aggressive initial attack, fewer containments, and no observation-only fires were actioned. In all, during August, several hundred fires were actioned successfully under this flexible approach.

Preparations prior to September 3 had placed a small project team on one contentious fire that was under control at 2800 ha in the area and had prepared initial attack for upwards of 20 new starts in the period. Because it was during the Labor Day weekend and nearing the end of the normal fire season, nonfire staff were brought into the system to provide backup crewing and support services by Friday to ensure availability through the weekend.

Then came Black Saturday, September 3, when a combination of overnight lightning acting on very dry shallow fuels and winds throughout the day reaching 70 kmh assured us of a very busy period. About 40 to 50 new fire starts and a breakaway of several fires previously under control occurred, with spread rates measured above 300 feet per minute.

As soon as the impact of Saturday's events unfolded, the Regional Fire Strategy Team was contacted. This group, made up of resource managers and the fire management officer, set priorities on problem fires within the region and directed the fire duty officers in command and control decisions. The assistant deputy minister was also contacted for briefing and to ensure that other agencies were made aware of the situation. Region staff contacted the Provincial Fire Centre to request added resources, including heavy water bombers, helicopters, and fire crews as well as the full complement of six provincial fire teams.

There are two facets of this grouping that represent important cogs in our fire system that I should describe further.

Fire Teams — Ontario maintains an annual contingent of six primary and six backup fire teams, representing what are known as short teams. Each has a qualified fire boss, suppression boss, service boss, and plans and records officer, and each team is formed on a basis of two teams per region. These people form the nucleus of a five-step project fire management team and are under alert and dispatch instructions by the province throughout the season. In the case under discussion, the four remaining uncommitted primary teams were activated, dispatched to the region, and assigned on the basis of three priority fires while one team assumed control of all northern fires.

Fire Crews — The Province of Ontario funds a basic initial attack/line crew contingent of 170 five-man fire crews that are hired, trained, and headquartered across the province, but highly mobile for this type of situation. All available crews were mobilized and en route by Sunday morning.

The Region meanwhile dispatched an evacuation team to assist the northern district to facilitate removal of residents of remote villages adjacent to some of the fires north of 52°, if required.

The deputy minister was requested to issue an Emergency Area Order covering a 7000-square-mile area of the region, where five fires posted an immediate threat to resource and private values. Under this order, about 500 residents and tourists were evacuated on Saturday night and Sunday. Road access was closed to the public and aircraft access to tourist facilities restricted. NOTAMS were also placed over each fire area where aircraft would be the predominant access to provide better control of airspace. By late Saturday night, most of these actions were in place in the region and the move against the fires was being planned.

Most of the key fires were totally obscured by dense smoke, some of which originated in the area just over the Manitoba border, and flying conditions were almost full IFR.

On Sunday the smoke still obscured the fire areas and a request was made to the province to supply high-level infrared for mapping. The BIFC unit was on site within hours. By 10:00 all fire teams had been assigned to priority fires and requests for manpower and equipment were pouring in, many of which were relayed to the Provincial Fire Centre to be supplied by other parts of the ministry and also Alberta, B.C., and other provinces.

Three projects, Kenora 73, Red 149, and a combination of three fires adjacent to them, were identified as the first priority for suppression action. One of these fires was by this time in excess of 75 000 ha and the others were of lesser sizes, but still large.

The Kenora District, site of the largest fire, was also busy with multiple new starts and the regional strategy team decided to remove Large Fire 73 from its overall management. The team, when assigned, reported directly to the region fire management officer for actions on this fire. This arrangement continued for about 2 weeks and was rescinded when the fire was being held.

In the past when large fires transcended district management boundaries, attempts were made to create unique fire environment entities separate from the basic management system. This caused considerable problems in creating them as similar, but stand-alone, entities.

In this case, only the management direction was removed to allow the district to concentrate on initial attack. Full integration of emergency services, information flow, and support services was maintained by constant consultation and agreement among the district manager, fire management officer, and project fire boss. This proved to be far less problematic and far more productive than past efforts.

Some special aspects of our large fire system were activated as well. Information services were upgraded to meet the increased demands of both media and internal management systems by the addition of professional communications staff from our head offices at the regional and provincial levels. This allowed proactive selection and dissemination of emergency information to calm public concerns. As well, two TACK communications systems were installed on fires to overcome the jamming that normally occurs on our normal VHF-FM low-band system.

Fire personnel rosters, which had begun to emerge in 1983 as computers became more operational, were used to search out special skill areas resident across the province in areas of aviation management, communications operations, fuel system operations, and others. Fire emergency compensation was invoked for nonunion staff involved in the activity. This recognized the high level of involvement of nonfire personnel in the system.

Indirect attacks, through the use of the Ontario Aerial Ignition Device, were part of several fire operations. Due to critical resource values, however, the efforts were prescribed only to those areas essential to contain or stop the fire progress. In total, perhaps only a few hundred hectares were deliberately fired.

Woods industry involvement was commendable and demonstrated how far we have come since 1980 in the training, availability, and performance of industry fire crews. The program, a joint venture between the Ministry of Natural Resources and the Ontario Forest Industry Association, has placed an estimated 100 seven-man fire crews on-line for initial attack and line-holding in the province. There are now just a handful of companies either not involved or whose involvement is well below an acceptable standard.

Native employment in fire has been in decline for several years, Their role is minor except in project fire situations due in part to their wishes to stay at home versus accepting extended employment off reserves, coupled with an increase in resource student employment within our ministry in such areas as fire crews. We solicit and get responses from native groups for project fire line work, based generally on a 2-3 week stint, in discrete reserve-oriented groups. Our recent situation developed about two 3000-man-days of employment in August and September.

The situation continued to build until about September 12, with over 1200 people involved. The evacuated communities and tourist facilities were reinstalled September 16 when a general demobilization of resources occurred, and fire teams were all returned home by September 17.

Looking to our future in Ontario, the province has opted for a more centralized form of command and control based on a regional organization process. By next spring operations planning, organization adjustment, and new systems are to be in place to provide a centrally based fire protection service to the ministry's resource management organization. Much of what was tried on for size in September will be incorporated into our new style. Also, and perhaps more importantly, much of what we lacked in project fire management is being recognized and will be dealt with over the winter. Priority setting, decision making, communications, mobilization of government and private resources, and resource evaluation criteria remain as problematic situations in our system.

Our past strength has been to react to a situation both quickly and positively. Our future will lie in our ability to prejudge, evaluate, and provide a more proactive approach as natural resources diminish in number and increase in value.

FIRE MANAGEMENT OPTIONS IN CANADA'S NATIONAL PARKS

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ABSTRACT

Fire management in Canada's national parks is facing other alternatives besides traditional suppression. The 1979 Parks Canada Policy permits a full range of options while the Natural Resources Management Process (NRMP) provides the framework by which specific options will be determined and approved. Banff National Park's lower Bow Valley contains a high capital development, a high visitation number, and a fire-prone vegetation. This provides a setting for a simulated fire program where the negative exponential distribution of fire intervals is reinstated through the use of randomly scheduled planned ignitions. Potential constraints to the realization of such a program vary from public and internal perceptions of such a program to the ability of matching the natural fire intensities in certain sensitive areas of the park. A vegetation plan approved through the NRMP is a key to fire management in national parks. Such a plan must initially be formulated on sound ecological principles and then modified in accordance to management requirements and constraints.

INTRODUCTION

National parks, once established for purposes of tourism and other economic reasons, are now recognized as a "means of preserving in a natural state, areas which are representative of the major natural environments of Canada" (Parks Canada 1979). Concurrently, fire, once considered a destructive force, is now recognized as a renewal agent and as a means of preserving in a natural state ecosystems that are fire-dependent. Given this, Canada's national parks can no longer consider suppression of fire as their sole alternative to fire management. Otherwise, the purpose of national parks is jeopardized and the mandate of leaving parks unimpaired for future generations of Canadians will be unfulfilled.

Fire management, defined as the use of fire to achieve land management objectives, is a relatively new concept for Parks Canada. Before 1970 fire was not perceived as a tool; fire prevention and control dominated. The seventies were witness to experimental burns, prairie maintenance fires, fire history and ecology studies, and fire effects assessments. Finally, in 1979 the adoption of a new policy that recognized fire as a natural process belonging in national parks culminated the metamorphosis of Parks Canada's perception of fire management.

Shortly after the policy's distribution, Van Wagner and Methven's (1980) paper on a philosophy for fire management in national parks was published and a workshop of fire specialists resulted in an approach to fire management within national parks. After this flurry of activity, external interests fell into a lull. Proposed interdisciplinary studies have lagged for lack of interest within the fire research community, some commissioned studies remain outstanding, and there is currently only one study under way within national parks by a fire researcher. In contrast, interest among national parks personnel has grown. For example, fire planning has been conducted in Banff National Park (BNP) since 1979. Park's staff have investigated numerous elements of the fire problem including historical fire regimes (White 1982), weather patterns during large fires, fuel appraisal, and vegetation succession trends. Whenever possible, the information gathered was keyed to the park's land classifications at the ecosite level (Holland and Coen 1983). This facilitated mapping and area analysis on a park-wide basis. Elk Island National Park and Pukaskwa National Park, among others, are scheduled to develop fire management plans. These initiatives are being jeopardized, however, for lack of professional and institutional guidelines.

Faced with the many unknowns associated with fire's effects and behavior, untrained and unsupported personnel, and a public immersed in Smokey the Bear's perception of fire as a destructive force, park managers are reticent about implementing fire management within national parks. Yet, if the task is not undertaken the implications, though wide-ranging (Agee 1974), raise particularly a serious concern for safety. Fire cannot be excluded indefinitely from fire-dependent vegetation.

This paper's purpose is to assist in defining the fire management alternatives in national parks. First, the general framework for resource management in national parks is presented before defining the existent framework for fire management. Banff National Park's lower Bow Valley, one of the more fire-prone, developed, and used portions of Canada's national parks, is used as a backdrop to demonstrate issues facing fire management in national parks. The relevance of Banff's fire management issues to Canada's park system is explored next and is followed by concluding remarks.

FRAMEWORK FOR RESOURCE MANAGEMENT IN NATIONAL PARKS

The overall guiding philosophy for natural resource management in Canada's national parks can be summarized by two words: minimal interference. According to the Parks Canada Policy (Parks Canada 1979), the responsibility of natural resource managers is "to ensure the perpetuation of naturally evolving land and water environments and their associated species". To assist them in carrying out their responsibilities, the Natural Resources Management Process (NRMP) was issued as a directive. The NRMP provides input to and in turn derives directions from the National Park Management Planning Process. The objective of the later process is the issuance of the Park Management Plan. This document, which contains the objectives of a park, is signed by the minister responsible for Canada's national parks after a series of public consultations.

The NRMP is composed of an array of steps but with a set of loops that permit the redirection of a particular natural resource initiative. The major steps of the NRMP germane to this paper consist of interim management plans, an ecologically integrated inventory, an analysis of the resource base, a conservation plan that ranks the priority of the issues arising from the analysis, and finally a set of management plans addressing each of the priorities.

A significant feature of the NRMP is that senior management decide at critical points whether the directions chosen are appropriate. This provides a beneficial feeling of support to natural resource managers while ensuring a flow of information toward the corporate structure of Parks Canada. Also noteworthy is the conservation plan. Within this plan, ever-scarce fiscal and human resources are allocated to specific natural resource issues in accordance with a priority. The ensuing ordered deployment of energy maximizes efforts.

While the National Park Management Planning Process influences the NRMP, it is the Parks Canada Policy that determines the direction of natural resources initiatives. The policy is clear on intent but retains flexibility to permit a wide range of activities to occur, defined partly by a particular park's circumstance. For instance, fire, along with other natural processes, is recognized as a natural process and as such it is to be allowed to function within a national park. The policy also recognizes that alternations to processes have inadvertently occurred and these should be rectified. In such instances where active resource management is necessary, a duplication of nature in terms of techniques is required; however, the policy also provides a series of circumstances under which fire's normal role can be manipulated. These are discussed in the next section.

FIRE MANAGEMENT IN NATIONAL PARKS

Although fire management in national parks has traditionally concentrated on suppression, prescribed burns and other activities noted in the introduction were carried out before the 1979 policy was approved. Since 1979, Elk Island National Park has continued burning for purposes of range enhancement, while in Banff National Park an experimental burn in a forested area was carried out this fall with others to follow in the spring. All of this is under the guise of "implementation of the fire policy".

Of all the natural forces, fire is the most controllable and applicable. Because of this, fire will likely be used in instances beyond rectifying past suppression actions or maintenance of a natural fire regime. Specifically, the Parks Canada Policy permits interference with a natural process where "a major control is absent" or where "the continued existence of a plant or animal species is rare or endangered or which is critical to representation of the natural region is threatened", or finally where "the population of an animal species or stage of plant succession which has been prescribed in the objectives for a park cannot be maintained by natural forces".

Moreover, the Parks Canada policy recognizes that park objectives are not always compatible with the unbridled fluxes characteristic of natural processes. Hence, the use of fire is constrained where "there may be a serious adverse effect on neighboring lands". If "public health or safety is threatened; or major park facilities are threatened", then there is further cause for the "manipulation of naturally occurring processes". Thus, outright fire suppression, fuel reduction, and plant succession manipulation are all possible fire management strategies within a national park.

That fire belongs in national parks has been made clear by the myriad of authors (Alexander and Dubé 1983) who have stated that the presence of fires in a fire-dependent ecosystem is a requirement for the perpetuation of such an ecosystem. Other authors (Van Wagner and Methven 1980) have made clear that the effect of a fire is not dependent on source of ignition. Whether the fire occurs due to random ignitions (lightning or accidentally man-started) or planned ignition (prescribed burn), the result of a fire is determined by its intensity, depth of burn, and fire interval. Thus, with a fundamental understanding of the ecology of an area and a good grasp of fire behavior and its effects, it is now feasible for a manager to consider achieving the objective of "perpetuating naturally evolving land and water environments and their associated species". This is particularly so since this objective can be attained without necessarily depending strictly on uncontrolled wildfires (Van Wagner and Methven 1980; Alexander and Dubé 1983). All that is required is to maintain a distribution of stand ages representative of natural conditions. Where stand flammability does not vary with stand age and the ignition pattern is random, the stand age distribution will approximate a negative exponential curve (Van Wagner 1978). In nonlethal fire regimes, it is the distribution of intervals between fires that takes on the negative exponential curve.

In large and remote parks a random pattern achieved solely through lightning ignitions is not inconceivable. But in other parks or parts of parks where the litany of restrictions to fire contained in the Parks Canada Policy applies, random ignitions are not feasible. The policy, however, does not discourage the use of carefully located and timed planned ignition fires to "duplicate natural processes as closely as possible". To achieve natural conditions, park managers could randomly schedule areas for planned ignition.

The criteria for use of planned ignition fires cannot be determined until a decision has been reached regarding what kind of vegetation a park should contain. The vegetation plan is critical. Such a plan must encompass considerations of not only the vegetation as a resource whereby evolutionary, biogeographic, and ecological trends are incorporated, but it must also take into account park values prescribed by the park management plan. The effect of a chosen vegetation mosaic will have a definite impact on other natural resources as well as processes and, of course, on park visitors. These effects must be compatible.

Finally, a plan must be realistic in the face of techniques available to achieve such a plan. Notwithstanding that the Parks Canada Policy prescribes techniques that emulate nature, fire may not always be used alone. For instance, in the boreal forest adherence to this policy would require using stand-replacing fires that are often uncontrollable. In other areas, because of previous suppression actions the use of low-intensity fires may no longer be possible; repetitive burns or mechanical means may be required to reduce fuels to an acceptable load. Such problems must be addressed by each park vegetation plan and it may be realistic that stands will need to be prepared by other techniques before fire can be used. Even those parks or areas of parks without constraints on the use of fire must prepare a vegetation plan. Such a plan must conform to the area's natural fire cycle.

Devising the vegetation plan to encompass all of the above features is a formidable task. It cannot be sidestepped not only for the reasons given above but also because it will be the vehicle by which fire management will pass through the NRMP and get approval. This is a key point, because without such an official sanction the required fiscal and human resources for fire management will not be made available. Whether the vegetation plan is based on an unbridled fire regime or an intense manegement of fire through planned ignitions, there is a basic requirement in both cases for trained personnel and logistical support. For all intents and purposes, Parks Canada currently has neither.

The generalities used so far are only useful in defining a framework for fire management in Canada's national parks. Through the example that follows we hope to fill some of that framework; however, because of the many issues associated with fire management in national parks it isn't feasible to address all of them here. This example restricts itself to the maintenance of "natural" stand age conditions in the lower Bow Valley of Banff National Park.

IMPLEMENTING THE POLICY: THE BANFF NATIONAL PARK EXAMPLE

Background

Outstanding challenges in implementing natural fire management plans within Parks Canada are provided by the heavily developed and visited southern parks. In this regard the lower Bow Valley of Banff National Park is exceptional. It is the most visited and probably has the highest capital development of any comparable area in national parks. The fire dependency of its vegetation, however, is a shared feature with many other similar areas. The exceptional nature of the lower Bow Valley clearly implies that if fire management is possible here, then it is quite likely possible in other national parks.

Recognizing that management of fire in its full context is still some time away, an interim plan has been prepared. The purpose of this plan is to upgrade Banff's fire management capability and help the park make the transition from total fire suppression to more naturally oriented management. The plan follows an approach similar to that recommended by Aldrich and Mutch (1973) in delineating fire priority zones and management units. Recognizing the park's historical regime of fires that would often threaten facilities, visitors, and park boundaries (White 1982), the interim plan requires rapid initial attack of all random ignition fires for the next several years. A wildfire (escaped fire) situation analysis procedure, however, should minimize costs and environmental impacts of suppression activities. In addition, the interim plan schedules several planned ignition fires to evaluate the potential for widespread use in the Canadian mountain parks. To aid in implementation, a helicopter initial-attack crew trained in planned ignition fire use is stationed in the park.

Planned Ignition Fire in the Lower Bow Valley

The interim plan provides immediate guidance for fire management in Banff National Park; however, in the long run, widespread use of planned ignition fire will probably be essential in areas such as the lower Bow River Valley near Banff townsite (Fig. 1). This area holds the park's largest component of fire-dependent montane vegetation and an important wildlife winter range (Holland and Coen 1983; Holroyd and Van Tighem 1983). But the Banff townsite and outlying developments, the Canadian Pacific Railroad, the Trans-Canada Highway, several million park visitors annually, and an interface with communities near the park boundary (Harvey Heights, Canmore) obviously preclude utilizing random ignition fire to achieve vegetation and wildlife management objectives; planned ignition fires appear to be the most feasible option. Thus, park staff prepared a planned ignition simulation program that illustrates an approach to maintaining "natural" stand age distributions.

The simulation was based on information gathered from the following sources:

1) Fire frequency and time-since-fire information was gathered from fire scar analysis. For example, as of 1880, warm/dry montane ecosites with Douglas fir and lodgepole pine had a time-since-fire distribution that approximated a negative exponential curve with a mean of 32 years (Fig. 2). A negative exponential distribution implies that these forests burned randomly with the annual probability of burning equaling the inverse of the fire cycle or mean time since fire (Van Wagner 1978).

2) Historic fire intensity information based on the portion of canopy burned (Fig. 2) shows that many fires in warm/dry montane ecosites left much of the canopy unburned, although total crown fires were also common.

3) Historic fire size information (Fig. 2) for similar forests in Jasper National Park (Tande 1977) shows that many fires were less than 500 ha in area.

Accordingly, 67 burn units were defined for the lower Bow Valley (Fig. 1). Table 1 provides for each unit, the area, year of last fire, and desired fire cycle. Based on the ecosite types found in a unit, each unit is assigned to one of three fire cycles: 20 years for open grasslands and aspen units that historically had short fire return intervals and require frequent fire for maintenance of open vegetation conditions; 40 years for units dominated by warm/dry ecosites with Douglas fir and lodgepole pine; and 60 years for northern aspects and streamside units that have a lower expected fire occurrence due to moister conditions. These fire cycles should maintain relatively low biomass accumulation, good wildlife habitat, and representative vegetation communities.

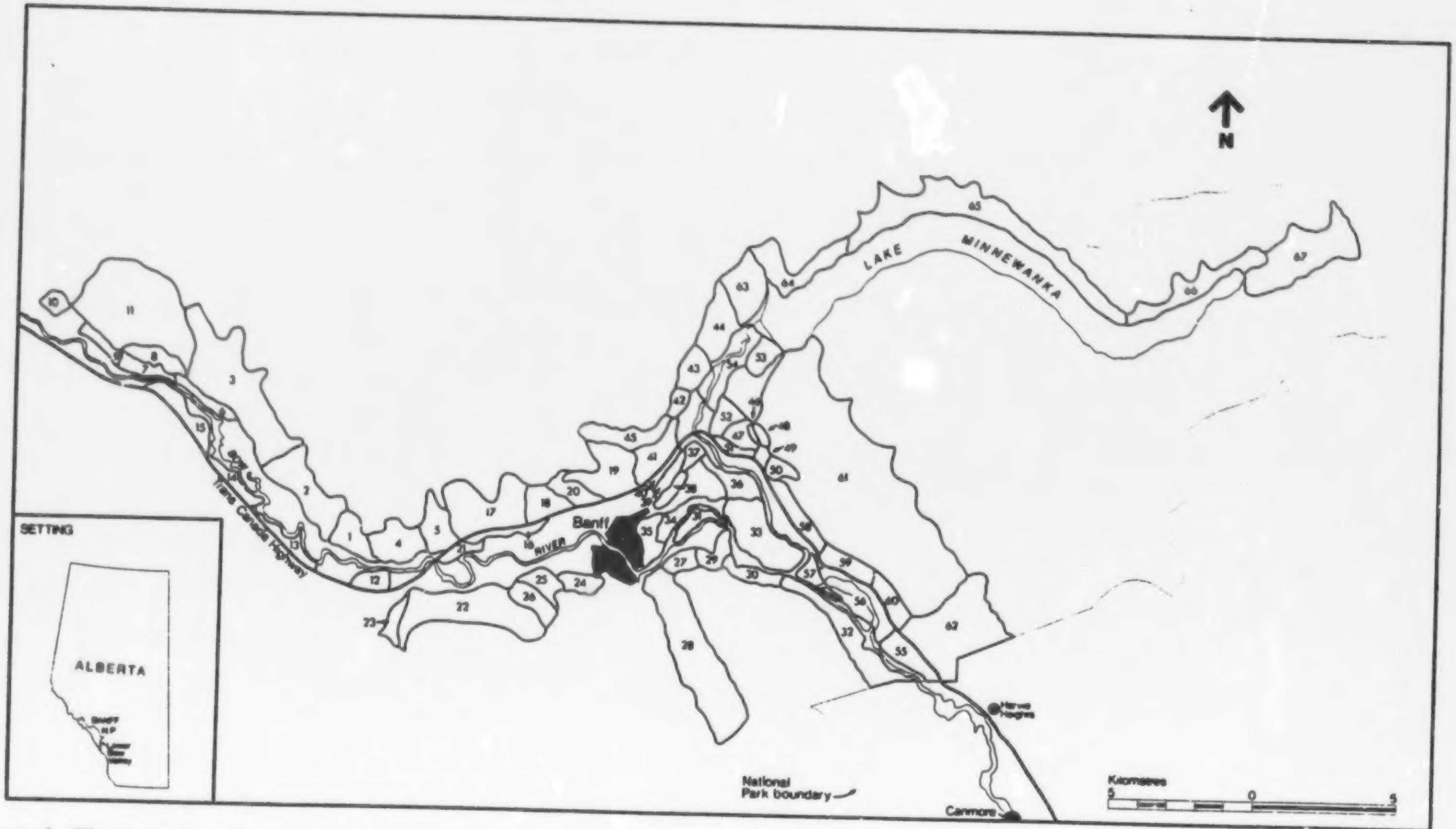

Figure 1. The lower Bow River valley showing planned ignition fire units. Numbers within units are keyed to Table 1.

Table 1. Lower Bow River valley planned ignition burn units with a simulated random burning schedule

Map	Area (ha)	Last fire year	Fire cycle	Simulated burn years (1986-2035)
1	112	1891	40	1987
2	362	1904	40	2008
3	900	1801	40	
4	375	1891	40	2035
5	281	1903	40	1991, 1992, 1993
6	69	1930	20	2011
7	82	1861	40	2035
8	84	1801	40	1998, 2010
9'	56	1881	40	1998, 2032
10	81	1881	40	
11	937	1881	40	
12	125	1881	60	1996
13	80	1891	60	
14	62	1891	40	2019, 2026
15	100	1925	40	2030
16	20	1903	40	1995, 2003
17	500	1903	40	1994, 2030
18	205	1903	40	
19	252	1923	40	2004
20	75	1914	40	2003
21	62	1903	40	
22	720	1891	40	
23	100	1891	40	
24	105	1881	40	1997
25	125	1881	40	1991, 2003
26	87	1891	40	2025
27	55	1921	40	
28	587	1840	60	1988
29	193	1881	40	2027
30	75	1841	60	
31	94	1881	60	
32	275	1841	60	1999
33	656	1897	40	
34	105	1928	40	2005
35	94	1881	40	2012
36	95	1906	40	1993
37	112	1897	40	1988
38	75	1897	60	2012, 2015
39	62	1897	20	1998, 2003, 2006, 2025, 2027
40	37	1897	20	1992
41	110	1897	20	
42	50	1905	20	2008, 2009, 2012, 2023, 2030
43	62	1889	20	2002, 2025, 2029
44	212	1889	40	
45	162	1889	40	2000, 2016, 2025, 2032

Continued on next page

Table 1 continued

Map	Area (ha)	Last fire year	Fire cycle	Simulated burn years (1986–2035)
46	18	1933	40	
47	750	1906	40	2021, 2026
48	28	1906	40	
49	56	1933	40	2007, 2029
50	68	1906	40	2012, 2023
51	62	1933	40	
52	281	1906	40	
53	131	1881	40	
54	143	1881	60	
55	169	1931	20	2009, 2012, 2035
56	225	1900	60	
57	75	1900	60	1999, 2005, 2034
58	200	1906	40	1993, 2027
59	162	1900	40	2035
60	100	1931	40	
61	2740	1870	40	2017
62	581	1900	40	1987
63	225	1881	40	
64	262	1870	40	1994
65	912	1870	40	1990
66	544	1870	40	2004
67	404	1870	40	

Simulating a Planned Ignition Burning Schedule

Recognizing that a random burning pattern may be an important factor in maintaining natural conditions, park staff used a computer program to simulate a random schedule for planned ignition fires. Each year all units are individually tested against a randomly generated number in the interval, $0 \leq N \leq 1.0$. If the number generated is less than or equal to the inverse of the unit's fire cycle (annual probability of burning), the unit is selected for burning during the year.

Table 1 provides a simulated schedule of when units would be burned based upon a run of the computer program for a 50-year period (1986–2036). As expected, units with 20-year fire cycles are scheduled more frequently than those with longer fire cycles. The random nature of burning is highlighted by burn units such as No. 45, which would be burned four times during the 50-year period, compared to many units that would not be burned at all.

Figure 3 shows the effect of the simulated burning program on percent area of units (40-year cycle) as broken down by time since fire. In 1986 (the beginning of the simulation) the time-since-fire distribution reflects the results of increasing efforts in fire suppression, which became almost totally effective 40 years ago (White 1982). After 50 years of simulated planned ignition fires (year 2036), the distribution is bimodel with some residual areas escaping burning. With another 50 years of simulated burning (year 2086), a negative exponential distribution curve is approximated that is similar to the 1880 situation (Fig. 3). The average unit time since fire decreases from 89 years in 1986 to 70.1 years in 2036, and to 45.7 years in 2086. The result is a time-since-fire distribution similar to 1880 conditions (Fig. 2).

Constraints On the Simulation

The simulation planned ignition program for the lower Bow Valley is obviously idealized; several factors would likely constrain the realization of such a program. For instance:

1) High-intensity crown fires are not infrequently a component of the area's natural fire regime (Fig. 2). Duplication of this phenomenon may not be possible, particularly in burn units 24 and 34, which are immediately adjacent to the Banff townsite.

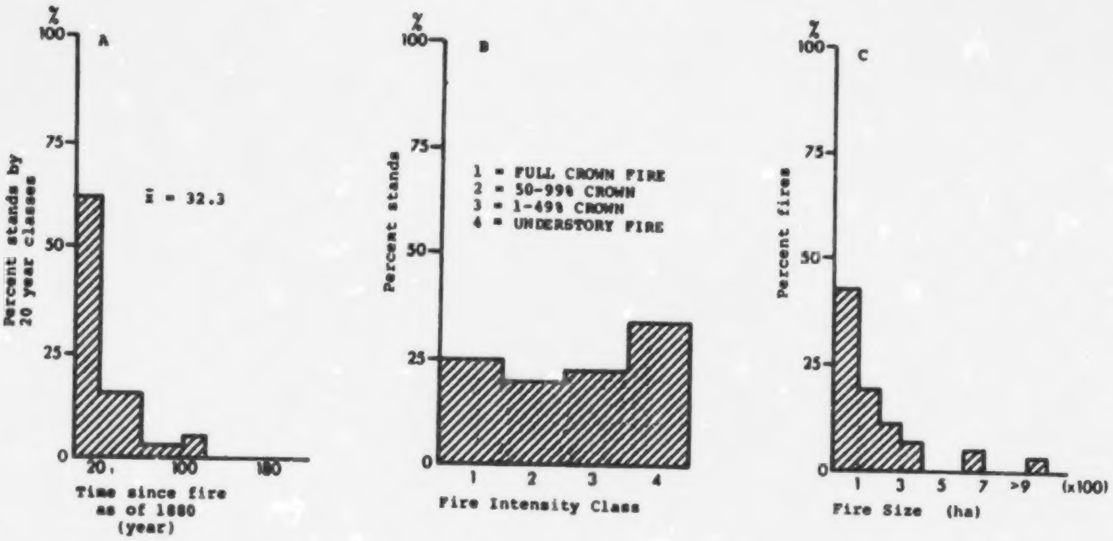

Figure 2. Time-since-fire distribution for warm/dry montane forest stands in BNP as of 1880 (Graph A), historic fire intensities based upon degree of crown mortality in warm/dry BNP forests (Graph B), and historic fire sizes in Jasper National Park from Tande (1977) for the period 1860-1910 (Graph C).

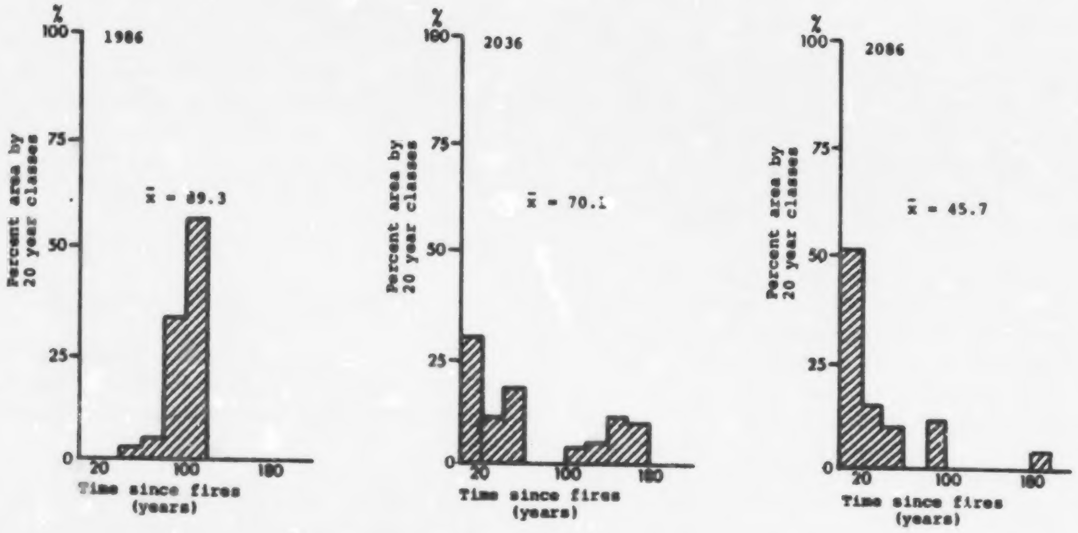

Figure 3. Time-since-fire distribution as of 1986, 2036, and 2086 for 40-year-cycle units as simulated by a randomly scheduled planned ignition fire program.

2) Many units contain areas with unique interpretion opportunities, vegetation, or wildlife resources. Trying to optimize benefits for all of these resources will be a complex problem. For example, expensive underpasses are being constructed under the Trans-Canada Highway to allow wildlife movement along traditional paths. Any planned ignition fires will likely need to take into account such capital developments while also designing them to maintain wildlife use patterns.

3) A random process for scheduling planned ignition fires is contrary to many managers' perceptions of when and where burning is required. For example, unit 61, a large and technically difficult unit, is scheduled by the simulation for burning in the year 2017 (Table 1). Would Banff's superintendent approve the burn given that it was selected simply by a "throw of the dice"? Also, some units are scheduled for frequent repetitive burns (e.g., burn units 39 and 42), while others would not be burned at all before 2036 (Table 1). The ecological ramifications of this random burning are not well understood, which is a concern because they are probably important.

4) The implementation of a burning program as simulated above would result in a dramatic change in current biophysical resources and aesthetics. Large areas would show abundant evidence of recent fire. At this time it is unknown whether park managers and the public will accept these changes. Obviously fire management implies whole-scale vegetation manipulation and thus must be guided by the objectives of a vegetation management plan.

5) To maintain rationality and continuity in the Bow Valley, program managers must maintain a long-term viewpoint (e.g., 100 years). With the mobility of staff and organizational changes, is this possible?

DISCUSSION AND CONCLUSIONS

The technical complexity of implementing a fire management program in Banff crystalizes the ramifications of Parks Canada's policy on fire. From this example and the progress in other Canadian national parks, we can make some general statements. Firstly, a fire management program must be within the confines of a park objective as expressed by a park management plan. Such a program, including the required budget, must be considered in the context of the Natural Resources Management Process.

Secondly, the fire management program must be defined by a vegetation plan. It would be contrary to national park policy to derive a vegetation strictly through fire management objectives. It must be recognized, however, that initial burns will and must be carried out for training purposes as well as for gathering knowledge on behavior and effects of fires within a specific area.

Thirdly, whatever distribution model of intervals between fires is considered "natural", it may at times require modification to fit the particular circumstances of a national park. Some consolation can be taken that in nature duplicity exists and the "natural" model does not necessarily occur nor is it maintained. Deliberate or inadvertent modifications through accident or nature itself do not necessarily imply a less "natural" vegetation. At all times, a long-term outlook must be maintained.

Nonetheless, fire management is likely to be perceived as futile when it is initiated under the guise of restoring "natural" conditions but for some reason results only in the modification of the unnatural state. Such reasons are many, varying from socioeconomic and political to improperly communicated objectives. Of all possible reasons, the least excusable would be a substandard ecological rationale. Obviously any criticism would be justified in such a case and would be detrimental to fire management in national parks.

The substantiation for a vegetation plan, based on fire history data as well as ecological knowledge of the area, is of course important. Fire histories, however, are interpreted mostly from the current generation of existing vegetation and literature, which, like ecological knowledge, has, comparatively speaking, only recently begun to be accumulated. Thus, fire cycle and fire regime estimates cannot be considered absolute. The only certainty is that over time revisions to the vegetation plan will be required.

Fourthly, in the initial stages a vegetation plan should address only the achievement of a "natural" vegetation. In fire-dependent ecosystems, this may require the use of random and planned ignition burn patterns within a natural fire cycle and with appropriate intensities and timing. Having achieved this, the next and succeeding stages consist of subjecting the plan through a process somewhat akin to an environmental screening in order to determine the impact of the projected vegetation mosaic on other natural resources, park values, visitors, and capital developments. Adjustments made to the vegetation plan subsequent to such a screening will necessitate repeated screenings. Finally, the costs of carrying out such a plan and the techniques available must be introduced in the deliberations. It is quite possible that in certain areas the ensuring scenario may result in reducing fire management to presuppression and suppression modes and for the time being rejecting "natural" objectives.

In most developed parks it is likely that the approach will conform to the Banff National Park experience. An interim fire management plan was drawn up based on interpreting the ecological inventory in terms of fire history and fuels. Such a plan, if approved, should provide opportunities to carry out burning tests where staff can be trained and fire behavior and effects can be assessed. With the experiences so gleaned, a vegetation plan can be formulated that meaningfully integrates the role of fire. Parks Canada's fire policy will thus be implemented.

The danger of high-intensity fires on most of Parks Canada's lands cannot be understated. Any park's fire management initiatives must as a basic requirement incorporate skilled and well-trained personnel. This requirement is perhaps the most important facet of fire management and one over which park managers have control and thereby can reduce the uncertainties associated with fire use. To acquire this cadre of personnel, there must be a deployment of fiscal and human resources for basic training. Parallel to this objective, an infrastructure in support of such individuals must be provided.

The achievement of the above will signal that Parks Canada will be in a position to evaluate and choose other fire management options besides suppression. In retrospect, the only alternative is this course of action, and it is prescribed in the Parks Canada Policy and the Parks Canada Act.

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SUPPRESSION OPTIONS AND ALTERNATIVES: A PRIVATE SECTOR PERSPECTIVE

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It's great to be in Banff, particularly at a meeting discussing common forest fire problems, and to have an opportunity for exchange with our Canadian neighbors. My comments will be confined to the operations of the so-called private timber protective associations, specifically the Clearwater-Potlatch Timber Protective Association. The association is responsible for forest fires within approximately one million acres in north-central Idaho. This area is predominantly high-valued commercial forest land of mixed ownership, with the largest portion of the land base in corporate ownership, the state of Idaho, and four federal agencies. The Cooperative Forest Protection Organization was formed in 1905 by the various timber interests who recognized the need to protect their interests from wildfire, with the objective of reducing fire-related losses and sharing the expenses.

Basically there are three elements required for a continual successful cooperative forest protection association: (1) a high-valued resource, (2) mixture of ownership (public and private), and (3) a definite interest in forest protection by landowners.

The fire management objective of the organization has remained consistent over the years, basically keeping the unwanted fire small and maintaining reasonable protection costs that are consistent with values protected. The organization is managed by a board of directors representing the major landowners within the protection area, and annually appoints the secretary-manager of the organization to oversee and direct operations.

This type of cooperative protection organization is unique today because most fire responsibilities have been assumed by public agencies, but the current Idaho Code continues to provide for this type of partnership between the public and private interests in cooperatively protecting their lands and resources from wildfire. The driving force, however, is the landowners' interest and direction to keep fires small and maintain reasonable costs.

In recent years some major changes occurred in the area that have had an impact on the organization's ability to meet fire control objectives. These include the flooding of the Dworshak Reservoir project, creating 175 miles of shoreline in a timbered, steep, and inaccessible area, which created a water-oriented recreation problem. During the same period of time, landowners began extensive programs of heavy investment in thinning of natural reproduction stands with considerable unabated slash and development of plantations on an expanding scale.

Following a fire hazard assessment of reservoir lands and adjacent state and private lands, and considering the reservoir management's desire to allow recreation activity to carry on into the higher burning indexes, a fire plan was developed. The plan called for control of all fires within the area to be controlled at 1 acre or less in size, and addressed mainly the fire prevention aspects of the water-oriented recreation activity. In order to attempt to meet the 1 acre objective, an initial attack was implemented utilizing a Bell Ranger helicopter, a 50-gallon bucket, and a two-man crew with support from boat patrol units, who are normally involved in fire prevention activities.

At about the same time (mid-1970s) a program was undertaken on the commercial timberlands to develop water sources for helicopter use and develop a retardant delivery system utilizing the larger-type crop duster aircraft available in the adjacent agricultural areas. The development of helicopter water sources included a survey of existing water as well as development using explosives or clearing around existing ponds with heavy equipment to facilitate helicopter use. The criterion for spacing of water sources was to have water available so that helicopter delivery time did not exceed 3 minutes between drops on a fire.

Agreements were made with the Idaho Department of Lands to contract jointly with a flying service for the single Rockwell Thrush Commander crop duster with tank conversion for retardant dropping. These aircrafts have 400-gallon tank capacity with 1200-hp engines.

Several airstrips were constructed within the protection area and several other grass strips were put into use. Most airstrips have water systems for quick loading of aircraft, and one centrally located strip has accommodations for liquid concentrate retardant. This project was directed toward a fast turnaround with small aircraft to support the helicopter operations. The air approach is in addition to the regular complement of manpower and equipment.

The results of this effort are rather difficult to measure. We have to consider changes in the annual fire weather, access, fuels, and many other items. I believe the simplest approach is by acres burned and personal observation of the effectiveness of the operation. Burned acres have been reduced when 997 fires (1966–1974 period) with an average burned area per fire of 2.5 acres are compared to the 754 fires (1975–1983 period) with an average burned area per fire of 0.9 acres.

My personal observation and opinion is that this type of air initial attack is effective and has reduced burned acres by assisting in controlling fires at a smaller size.

AERIAL IGNITERS PROVIDE A NEW DIMENSION TO INDIRECT ATTACK

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ABSTRACT

This paper reviews the unique aerial ignition device developed originally in Australia and the chronological work in Canada that eventually produced the Aerial Ignition Device and the Helitorch. It is of interest to note that the project has gone full circle in that Australia has purchased several Canadian aerial igniters. The concept of aerial ignition has created international interest in the prescribed burn field and in wildfire suppression. The late 1970s and early 1980s saw significant use of both the AID and Helitorch units in Canada and the USA. The record fire seasons of 1980–82 in Alberta provided the opportunity to carefully evaluate the aerial igniters for indirect attack. Extensive burnout and backfire operations are described and evaluated, and recommendations are presented. The observation was made that indirect attack was most successful during peak burning periods when direct attack was least effective.

INTRODUCTION

The first development work on aerial igniters, as many of us know, was done in Australia in the early 1960s (Baxter et al. 1966). A policy introduced in 1954 required rotational prescribed burning to reduce fuel buildup on over 200 000 forested hectares (500 000 acres) annually. This obviously required improved ignition techniques, and a research project eventually yielded a unique aerial igniter that automatically dropped incendiaries from aircraft. The incendiaries were capsules of potassium permanganate injected with ethylene glycol.

The follow-up in North America originated in Alberta at the Northern Forest Research Centre (NoFRC) in 1971 in response to a request from the Yukon Forest Service. A fire that had jumped the Pelly River prompted the Yukon fire control staff to request development of an aerial igniter for backfiring and burning-out in inaccessible areas using natural barriers (Lait and Taylor 1972). The Pacific Forest Research Centre (PFRC) eventually produced two aerial ignition systems following over 5 years of intensive research and development.

CANADIAN EVENTS

The prototype Canadian mechanism, built in 1972 and utilizing the Australian incendiary capsules, was hand-loaded and hand-driven and mounted in a helicopter cabin (Ponto et al. 1974). The operator placed incendiary capsules in a rotating chamber and cranked a drive handle that injected the glycol and released the capsule through an exit tube. The prototype was not totally reliable and had limited capacity; it did, however, provide a means of testing aerial ignition in Canadian fuel types.

Following preliminary testing and positive feedback from the prototype results, the Alberta Forest Service (AFS) proceeded to design an improved model (Kruger 1975). Major changes produced an automatic drive that injected and dispensed spherical incendiaries rather than capsules. A hopper fed the spheres into three injection chambers, which increased the ejection rate significantly. Since safety was a major concern, the mechanism was suspended below the helicopter and operated remotely. This created two problems: (1) the machine did not "fly" consistently, and (2) reloading or adjustments required landing.

At this point Gary Lait, the Canadian Forestry Service technician at NoFRC responsible for the aerial igniter project, was transferred to PFRC, teamed up with John Muraro, and the results are well-known. The PFRC Aerial Ignition Device (AID) was eventually tested and commercially produced (Lait and Muraro 1979). It is interesting to note that the project has gone full circle in that the Australians have purchased several AID machines.

Concurrent with the production of the AID, Muraro was experimenting with the more spectacular "flying drip torch", which was being developed for igniting coastal slash burns. The first model was simply a drum of diesel-gas mixture with a wick and valve suspended below the helicopter. The wick would be lit, the valve opened, and the helicopter would run an ignition pattern until the drum was empty. Later models were fitted with a solenoid and electric arc for remotely controlling ignition and fuel rate. The gasoline-diesel mixture was not satisfactory because it often broke up and burned out before reaching the ground. A gelled fuel solved this problem and the Simplex Helitorch joined the AID machine as a fully operational aerial igniter. Both mechanisms are described in detailed manuals that the reader is referred to for specific operating information. (Lait and Muraro 1979; Missoula Equipment Development Centre 1981).

Fire Suppression Implications

By 1979 a number of AID and Helitorch units were in use in both Canada and USA. Most of the early experience with the two aerial igniters was in association with prescribed burns, although backfire and burnout operations were attempted in the Yukon, Northwest Territories, Alberta, and Ontario.

The 1980s in Alberta have been described in an earlier paper and it is obvious that the back-to-back fire seasons were associated with some of the most severe fire weather in Alberta's history. To appreciate the severity, consider this statistic: area burned from 1979 to 1982 was approximately 7 million acres, equal to the area burned from 1947–1979. During the record fire seasons a specialty team was assigned to designated fires to explore the opportunities for direct attack using aerial igniters, and evaluations were made on the basis of cost, success, and safety.

One significant feature of fuel types in northern and central Alberta is the horizontal continuity of highly flammable stands, compounded by the lack of water bodies found in Saskatchewan, Manitoba, and Ontario. Wildfires have made many uninterrupted runs as a result. The most memorable is the Slave Lake Fire of 1968, which traveled 40 miles in 10 hours. With the predominance of the flammable black spruce type, the fuel continuity problem, and the recent severe fire seasons, the AFS has weathered many difficult fire suppression challenges compounded by high spread rates.

During the 1980s it has been decided to utilize the aerial igniters for burnout and backfire operations on going fires. The first large-scale operation was a burnout in Fire DF3-10-80 using the AID. Indirect attack was taken with bulldozer units and 10 miles of fireguard were burned out and secured.

Fire DND-4-80 provided the opportunity to determine the potential of backfiring from the air during the peak burning periods when the fire front had eluded direct attack attempts and was making major advances. This fire provided the experience necessary for developing ignition techniques and determining the distance of convection indraft for conifer crown fires.

At this point, let's define the terms backfire and burnout in relation to the subject of indirect attack. A backfire is an extensive fire set along the inner edge of a fuel break in the direct path of a going wildfire. The backfire is ignited at a proper distance from the advancing wildfire to ensure influence of the convection indraft. The objective of a backfire is to halt or retard the progress of a going wildfire.

A burnout is a less-vigorous fire set inside a fuel break, but not in the path of a going wildfire or under the influence of convection indraft. The objective is to reinforce an existing fire line or fuel break, thus speeding up line-holding and mop-up.

During August of 1981, the town of Swan Hills was threatened by Fire D53-23-91 approaching from the northwest. The Swan River was designated as the last stand and a backfiring team was positioned accordingly. Gelled fuel was prepared to ensure ignition in the tall timber stands, and two 206 helicopters with Helitorch units and a 206 bird dog aircraft with a fire behavior officer waited for the wildfire to approach. As the fire front crested the height of land leading into the river valley, backfiring commenced mid-slope between the river and the head fire. The combined effect of upslope conditions and the convective indraft produced a high-intensity backfire that rapidly moved toward the top of the ridge. The resulting effect was dramatic as the two fire fronts met and lifted the smoke pall well over the river valley, creating a "tunnel" that allowed the bird dog helicopter to patrol the backfire zone. A final ignition line was run along the river edge and again the topography and residual heat from the backfire zone drew the fire upslope, leaving a very clean burn to the water's edge. The wildfire did not break through the backfire at any point and no spotting problems occurred over the 2.5 miles of operation.

The most extensive aerial igniter operations took place in 1982, the worst fire season in Alberta's history. Backfiring and burnout became an integral part of the all-out fire suppression effort called for during the mid-June fire bust, demonstrating that aerial igniters have indeed provided a new dimension to indirect attack.

CONCLUSIONS

1. Aerial igniters are effective tools for implementing indirect attack operations on going wildfires.

2. Indirect attack was most successful during the peak burning period when direct attack was least successful.

3. In general, backfire ignition should be as close to the fire front as possible to ensure continuous influence of the convection indraft. Most backfires in 1982 were ignited 5–10 minutes ahead of the approaching wildfire.

4. In association with the severe fire hazards, one barrel of gelled fuel produced approximately one mile of backfire in both pine and spruce stands. Flying speed was 40–45 miles per hour and flying height about 20 feet above the tree tops.

5. The optimum indirect attack unit was 1-206 w/AID, 1-206 w/Helitorch and 205 w/bucket for support.

6. Indirect attack costs ran about $600/mi. using the above unit, compared to direct attack cost of about $30 000 for the same mile of line.

7. A team consisting of ignition boss, fire behavior officer, and mixer is required for safe yet aggressive large-scale indirect attack operations.

8. The Helitorch is not compatible with operations requiring manpower support. The risk of gelled-fuel contacting fire fighters or equipment operators is not acceptable.

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FOREST FIRE MANAGEMENT IN AUSTRALIA

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INTRODUCTION

Australia is mainly a pastoral country. The area of potentially productive forest is only 30 million hectares, or about 4% of the total land area. Of this area only 15 million hectares are productive forest managed by state forest authorities, other government agencies, or private companies.

About one-quarter of the country is a vast arid region extending through central Western Australia, the Northern Territory, and South Australia, where the average annual rainfall is less than 250 mm. This region receives no fire protection whatsoever and normally there is insufficient fuel to carry a fire. Widespread heavy rain from tropical rain depressions occasionally occurs in central Australia, causing abundant grass growth, and fires, often caused by lightning, subsequently burn unchecked over millions of hectares.

In the summer of 1973–74 unprecedented rain fell throughout the arid zone. Later between June 1974 and February 1975, when the continuous pastures cured, fires burnt more than 117 million hectares (15% of the area of the continent) (Luke and McArthur 1978). Stock losses as a result of burning were generally light, but often the loss of forage caused extensive stock losses during the dry season that followed. The total cost of these fires was not assessed. In western New South Wales alone, where nearly 4 million hectares burned, the losses were estimated at over $5 million, made up mainly of fencing (Cheney 1976).

A further 25% of the country, mostly in northern Australia, is an area of regular hazard where organized fire protection is seldom deemed necessary. This is an area carrying coarse tropical grasses, often in association with open tropical forests or woodlands. The main land use is beef cattle-grazing, and graziers regularly burn the coarse grasses soon after they cure to obtain a fresh, green pick through the dry season.

Of the 50% of the country that receives fire protection, forest services and other government agencies are responsible primarily for the protection of public lands (about 2% of the total area), while individual owners and volunteer brigades are responsible for the remainder. The volunteer bush fire brigades are also largely responsible for fire suppression in country towns and in the urban-forest interface that occurs on the outskirts of all major Australian cities.

Forest Vegetation

True forests are confined to a narrow strip mostly within 200 km of the east coast of Queensland, New South Wales, and Victoria and the southwest corner of Western Australia; a fairly large proportion of Tasmania is forested.

There is a small area of tropical and temperate rain forests (1–2 million hectares), which are dense, closed-canopy, layered forests and except during extreme droughts, are seldom flammable. The foliage of the numerous individual species is often of low flammability, and high decomposition rates within the forest prevent the buildup of flammable surface litter.

The vast majority of the forests are sclerophyll forests dominated by the genus *Eucalyptus*, containing more than 600 species. Some species that grow in wetter locations are fire-sensitive, but most species have developed traits that enable them to withstand fires of high intensity.

The most flammable forests are the dry sclerophyll forests. In spite of the large number of the eucalypt species, forests across the country share some common characteristics that have an important bearing on fire management.

- The dimensions of the foliage of eucalypt species vary little, and leaf and twig litter builds up a porous, flammable fuel bed with a fairly uniform density of around 60 kgm^{-3} regardless of the forest type or the age of the fuel bed.
- Trees have a self-pruning habit that rapidly provides a gap between the tree crowns and the surface fuels.

- The trees have bark characteristics that, depending on the species, provide a most suitable firebrand material for both long- and short- distance spotting.

- Understory species are flammable and mostly develop a structure that is conducive to the rapid spread of fire.

It is apparent from the traits possessed by eucalypts that they have been long associated with fire (Jacobs 1955). In addition, within the forest other flora and fauna have requirements that are usually met by a particular fire regime (i.e., a particular season, frequency, and intensity of fire). The key to sound forest management is a fire management plan that gives a proper balance of fire regimes to meet the economic, aesthetic, and biological demands on the forest.

Planning for "Worst Possible" Fire Danger

The concept of planning for "worst possible" fire danger has been adopted by most Australian fire control authorities to establish protection standards for both native forests and exotic plantations. Although "worst possible" conditions can never be defined, the concept does allow the forest manager to identify important factors that determine the behavior of damaging fires and to assess the likely frequency of disasters.

Conflagration fires require the presence of all the following elements:

- drought of sufficient intensity to reduce the moisture content of the dead fuels to a uniformly low level and induce a significant moisture stress in understory plants;

- the simultaneous occurrence of strong winds, high temperatures, and low humidities;

- heavy and continuous loads of fine surface fuels; and

- an ignition source that occurs during or before the above predisposing conditions.

When preparing an Australian forest fire danger rating system, Alan McArthur, to many the father of practical fire management in Australia, used the conditions measured in Melbourne on January 13, 1939, to establish an index of 100 on his fire danger rating system and thereby define the likely "worst possible" weather conditions. Below-average rainfall during the preceding winter and spring allowed the moist mountain forests to dry out and allowed fires lit for clearing purposes to burn on into summer. On January 13, after 2 weeks of heatwave conditions, gale-force summer winds fanned hundreds of fires through the mountains of Victoria and southern New South Wales. Huge areas of the most valuable forest in the country were killed or severely damaged and 71 people lost their lives. The prevailing weather conditions recorded at Melbourne were as follows:

- a drought period of more than 8 weeks duration;
- temperature of 46°C;
- relative humidity at 8%; and
- wind speed at 36 kmh^{-1}.

On McArthur's scale, at an index of 1 fires are self-extinguishing, while at an index of 100 fires are totally uncontrollable. Subsequent experience has shown that in most undisturbed forest fuels, suppression is impossible above an index of 50.

Ignition sources in the past were often escapes from clearing fires or burning-off for other agricultural purposes. These may change in the future, as ignitions from power lines or deliberate incendiarism appear to be of increasing importance. Lightning will remain a continuing ignition source.

Heavy loads of fine litter fuels accumulate rapidly in all eucalypt forests. In most forests, a fuel level of 20 tha^{-1} will result in catastrophic fires if the other three criteria occur simultaneously. The structure and self-pruning habit of the eucalypt forest, however, mean that where fuels are kept below 10 tha^{-1}, crown fires will not occur even under extreme conditions.

On February 16, 1983, Ash Wednesday, weather conditions, fuels, and ignition sources combined to produce the most devastating fires since 1939 in South Australia and Victoria. Fire management policies were severely tested in several states.

FIRE MANAGEMENT OPTIONS

There are a number of options for fire management in Australian native forests and exotic conifer plantations. In the past, fire management practice has been constrained by the resources available and may have been very different from official fire management policy.

"Let Burn"

Although the idea of allowing fires to run their natural course has only recently been promoted as a possible official policy option, the practice has in fact been widespread in remote areas in the past. Because manpower and resources were small, fires were allowed to burn in remote so-called 'unproductive' forest and suppression was not attempted until fires burnt closer to more-valuable commercial forest. Colorful terms arose in the bushman's vocabulary and stories of 'steering' the fire away from valuable assets by backburning gave credence to a degree of control over bush fires that had never existed. Suppression was possible only while fire danger conditions were mild and fuels kept light by frequent uncontrolled fire.

Historically throughout Australia, the folly of a "let burn" policy has become apparent when extreme fire weather conditions have blown the fires out of control into populated rural and urban areas, causing extensive damage. This has happened at different times in different states, and usually was the catalyst for major changes in rural fire protection policy. The latest disaster of this type was in Tasmania on February 7, 1967, when extreme conditions drove forest fires into the outer suburbs of the capital, Hobart, killing 62 people and destroying over 1400 buildings. There were more than 81 uncontrolled fires burning on the morning of February 7 prior to the start of extreme conditions; some had been burning for several weeks (McArthur and Cheney 1967).

Today forest fire control officers consider that there are no areas in the forest zone of southern Australia sufficiently large or isolated to allow fires to run their natural course. Nor are there areas with extensive natural barriers of rock or lakes as in parts of North America, and no guarantee can be made that fires will remain within the forest or park zone and not damage valuable timber resources or adjacent private property (Cheney et al. 1978).

Also, in most states there is now specific legislation prohibiting an occupant from allowing fires to run uncontrolled on his land during summer. Even so, there is evidence that the frequency of uncontrolled high-intensity fire is increasing and causing a change (sometimes barely perceptible but sometimes very obvious) from a forest vegetation to vegetation with a woodland or heathland structure.

The let burn policy has been proposed by some "environmental" enthusiasts for wilderness park areas in southwestern Tasmania and northern Australia.

Total Suppression

This management option (sometimes called complete protection from fire) relies on the buildup of a large suppression force designed to contain fires quickly as they occur. Presuppression activities are limited to the construction of firebreaks or access trails, from which it is hoped to establish control lines.

This option is politically the most attractive. The manager is relieved of the responsibility of undertaking fuels management with all its inherent ecological and environmental complications, and the wildfire, when it occurs, is either an act of God or some other irresponsible poltroon unaware of the human suffering and economic losses fires can cause. The politician can impress his constituents during a fire disaster by authorizing virtually unlimited suppression expenditure (particularly if it involves the latest and greatest technology) regardless of its likelihood of success. And success is indeed unlikely as the manager is inevitably faced with a fiscal drought during intervening mild seasons and is unable to carry out the necessary preparations and training to use sophisticated equipment efficiently.

Total suppression has been attempted in both native forests and exotic plantations. Where it has been attempted without fuels management, it has been found hopelessly inadequate under "worst possible" conditions. Two case studies of forest types where total suppression has been attempted will be discussed briefly.

Eucalypt forest managed for short rotation pulpwood production, Eden, NSW

A large area in the south coast of New South Wales characterized by coast ash (*E. sieberi*) and stringybark species had a history of repeated fires that had damaged the forest so severely that there were few trees of sawlog potential. The average yield of this degraded forest is 100 tha^{-1} of pulpwood and sawlogs. Intensive harvesting to produce chips for Japanese paper manufacturers was commenced in the early 1970s. The initial coupes were 800 ha or approximately 2000 acres. Clear-cutting on this scale had not been witnessed in Australia and it galvanized environmental enthusiasts into action. Such was the pressure on the NSW forest service that the service abandoned the recognized fire protection measure of postlogging burning, and reduced the coupe size to an average size of 12 ha with alternate coupes being logged.

By 1980 the annual cut was 6000 ha in a checkerboard of tiny alternate coupes, which effectively prevented broad-scale fire protection measures such as rotational prescribed burning of the uncut forest and postlogging burning of harvested coupes. In both cases the small size of the coupe and the checkerboard distribution of logged areas throughout the concession area (297 248 ha) made the burning operations unsafe and prohibitively expensive. In addition, the pulpwood operations left small mountains of bark residues on landings. These have the potential to ignite spontaneously and so were burnt during the winter months. Like many organic debris fires, these bark heap residues could smoulder for several months, and so, burnt or unburnt, they provided a high potential for ignition within the forest.

Suppression strategy was to have rapid detection with fire towers and aircraft patrols on days of extreme fire danger. All forest operations were closed and the work force was placed on standby at strategic locations to enable rapid initial attack to most parts of the forest. Equipment was mainly ground tankers (3 × 850 gal., 2 × 300 gal., and 5 × 100 gal.) with support from bulldozers.

On November 18, 1980, a forecast day of extreme fire danger, a fire broke away from a smouldering bark heap. The fire origin was close to a tower and was detected almost immediately. Two tankers reached the fire within 20 minutes of detection and a heavy bulldozer arrived about 10 minutes later. The fire was burning partially in uncut forest and partially in logging slash, and initial attack failed immediately.

The fire burned 42 000 ha in less than 7 hours. Rates of spread up to 6 kmh^{-1} were recorded and firebrands were thrown at least 15 km (the outbreaks of spot fires were limited by the Pacific Ocean). This fire burnt a final area of 45 000 ha or almost 15% of the concession area, much of it regenerated forest less than 10 years old.

In spite of the extreme weather conditions, the behavior of the fire was greatly moderated when it ran into two fuel-reduced areas. One of these was an area of uncut forest that had been fuel-reduced 12 months previously. The fire was stopped completely in this area, reconfirming the virtues of fuel reduction by prescribed burning. In the second area, a head fire ran into some compartments of 8-year-old forest that had regenerated on an area where the logging slash had been burnt by a previous wildfire. Although the forest was only 10 m high, the area was carrying insufficient fuels to support a crown fire and in parts the fire self-extinguished during a period of low winds.

Management changes now forced by the bitter experience of this fire include larger logging coupes of up to 100 ha fitted sensibly to natural topographic boundaries, postlogging burning to remove logging slash, and prescribed burning to reduce fine fuels in the uncut forest.

Pinus radiata plantations in South Australia

Extensive plantations of *P. radiata* have been planted in the temperate areas of Australia. These are mostly considered fire-sensitive and afforded complete protection from fire, although trees older than 28 years can withstand fires up to 200 kWm^{-1} (60 BTU sec^{-1} ft^{-1}) and suffer only minor cambial damage (Nicholls and Cheney 1974).

In the southeastern portion of South Australia, the topography is generally flat and the plantations are divided into compartments of around 25 ha surrounded by 10-m and 20-m firebreaks. Firebreaks 60 m wide subdivide larger units.

Fire suppression is carried out using water tankers and hose lay. Major tankers carry 2500–3000 L (660–800 U.S. gal.) of water and 360 m (1200 ft.) of 38-mm (1½ in.) lined percolating canvas hose in 30-m lengths. Backup water supplies are provided by 5000-L (1320 U.S. gal.) supply tankers. There are 12 frontline units and 6 backup units in the southeast region. Fire edge suppressed by water is consolidated by small John Deere 350 bulldozers fitted with front-mounted snow-plow-type blades to construct a fire line to mineral soil (Geddes and Pfeiffer 1981).

In 1979 a fire started within the plantation and burnt at rates of 3–4 kmh^{-1}, killing 3500 ha of pine plantation less than 20 years old. Damage was about $3 million.

In 1983, eight fires started under extreme fire weather conditions and burnt 18 500 ha of state-owned plantation (23% of the pine forests in the district). One major fire traveled more than 65 km (40 mi.) across grass and scrublands before entering the plantations. Suppression forces were unable to halt the fires either in grasslands or in the forests; the total area burnt was around 120 000 ha.

All firebreak systems broke down and although a small fuel-reduced area around a forest township reduced the intensity of the fire near the township, this area was burned by slower-spreading flank fires. The royalty (stumpage) value of the plantations burnt is estimated to be $100 million.

These are two examples that illustrate the failure under "worst possible" conditions of policies relying on fire suppression alone without substantial fuel reduction programs. The possibility of these conditions and losses had been predicted (Handcock 1977). Alternative fuel reduction programs had been recommended and demonstrated. In the future, courts may find forestry organizations negligent if they refuse to undertake established strategies to reduce fire behavior and rates of spread.

The use of large air tankers has been tried in Australia and is under continuing review as part of Project Aquarius. They have been demonstrated to be ineffective under extreme fire danger conditions (FFDI over 50) (Cheney et al. 1982). Few experienced fire control people believe that there will be any suppression technology that can be effective under extreme fire danger conditions in the foreseeable future.

Broad-area Fuel Reduction

To date the only effective way of reducing fuels over large areas is by low-intensity prescribed fire, so in Australia broad-area fuel reduction is synonymous with prescribed burning. In most eucalypt forests the aim of fuel reduction programs is to keep fine fuels (fuels less than 6 mm in diameter) on the forest floor to less than 10 tha^{-1}. This will prevent crown fire formation in medium to tall forests and will limit the rate of spread and damage done by wildfires. The frequency of burning is determined by litter accumulation rates; burning rotations are normally between 5 and 10 years.

Prescribed burning is practiced to some degree in all Australian states but most widely and expertly applied in Western Australia. The Forests Department is responsible for protecting 2 010 000 ha of state forest and timber reserves. After disastrous bush fires in 1961, systematic prescribed fire was applied to the forest, using both ground and aerial ignition, so that by the end of the decade 21.3% of the forest estate was burnt annually. Areas were initially reburnt after 4-5 years. During the next decade average annual prescribed burning was reduced to 16.2% of the protected area.

There were several reasons for this reduction. Most heavy fuel accumulations had been reduced, and after the second rotation burn rates of fuel accumulation were slower; larger areas of forest were being regenerated and cannot be burnt until the trees are more than 15 years old; and the fire management program had improved.

The efficacy of the burning program is difficult to quantify. Certainly there have been no major fires since 1969, when all areas were brought under the fuel management program. The area in general has a lower frequency of large fires over the last two decades than comparable areas in Eastern Australia (Cheney 1976), and a comparison of fire statistics for comparable dry forest areas in Western Australia and Tasmania for the decade 1971-81 shows that although Tasmania has fewer wildfires, the average area burnt is greater both per wildfire and when expressed as a fraction of the area receiving protection (Table 1). During this period the average wildfire burnt 15 ha in Western Australia and 270 ha in Tasmania.

Table 1. Comparison of prescribed burning and wildfire occurrence in dry forests in Western Australia and Tasmania. Annual averages for decade 1971-1981[a].

State forest service	Total area protected ('000 000 ha)	Fraction of area protected burnt by prescribed fire (%)	Number of wildfires	Fraction of area protected by wildfire (%)
Western Australia	2.01	16.2	370	0.3
Tasmania	0.72	2.6	68	2.6

[a] Source: Forest Service annual reports.

Western Australia, however, has not experienced the combination of numerous ignition sources and extreme fire weather that would test the program under "worst possible" conditions. The most notable potential fire disaster was in April 1978 when 90 fires burnt in and around state forest, drawn by gale-force winds with mean speeds of 40–60 kmh^{-1}. Many fires were held up in light fuels on areas recently prescribed burnt and the damage was assessed as light. Temperatures were fairly low (30°C), however, and relative humidities high (50–60%), so the forest fire danger index was only 20, or 20% of "worst possible" conditions.

Most fire control foresters are convinced of the efficacy of prescribed burning and will point to examples where recent (1–2 yr. old) prescribed burns have stopped high-intensity wildfires (e.g., Billings 1981). The benefits of reduced fire intensity and rates of spread are more difficult to quantify in terms of reduced damage and area burn, although fire fighters will testify to the dangers and difficulties of suppression in heavy fuels. Critics, however, remain unconvinced and are concerned about possible adverse environmental effects of repeated burning of large areas at regular intervals.

Management by Prescribed Fire Regimes

The concept of multiple use—the use of a given area for several different purposes—has been accepted by Australian foresters as a desirable objective of forest management. Unfortunately, it has bred the misconception that given areas can support a whole range of activities equally well. This is not possible; priorities must be set and each area managed accordingly.

In Australia, the obvious tolerance of many eucalypts to fire and the economic consequences of uncontrolled high-intensity fire led most people responsible for fire control to embrace prescribed burning as a means of limiting the losses caused by high-intensity wildfires. Opinions on the benefits of prescribed fire rapidly became polarized, with opponents being concerned about loss of species of flora, destruction of native fauna, loss of nutrients, and long-term decline in productivity. Now a more rational approach is being taken and the use of prescribed fire regimes to achieve several management objectives is gradually being accepted. The acceptance has been slow because management by fire regimes requires the following:

- reasonable security from unplanned fires of high intensity;
- an understanding of the biology of important components of the ecosystem so that a suitable fire regime can be planned; and
- an understanding of fire behavior so that the fire regime can be put into practice.

The only state where these criteria are met is in Western Australia. Here an area of 40 000 ha has been set aside where management for native fauna receives priority over management for timber production. In this area reasonable security from extensive unplanned fires has been obtained by the Department's policy of regular low-intensity prescribed burning. Research has shown that the ecology of two important marsupials in the area is closely tied to specific fire regimes.

The Tamar wallaby (*Macropus eugenii* Desmarest) lives in thickets of a leguminous shrub that requires fire every 20–30 years to regenerate. In the absence of fire the shrubs die and the habitat becomes better-suited to gray kangaroos (Christensen et al. 1981). The small rat kangaroo or woylie (*Bettongia penicillata* Grey) is also dependent on fire in a more subtle way. The diet of the woylie consists largely of the underground fruiting bodies of a hypogean fungus. The productivity of the fungus is related to the availability of nitrogen, which in turn is related to the vigor of the understory plants. The density of one of these species, *Bossiaea ornata*, which is capable of fixing nitrogen, is critical to the woylie as shelter from its predators (Christensen et al. 1981); shrub density can be altered by prescribed fire.

A tentative management plan for this area prescribes different fire regimes to provide the following:

- protection for the area by maintaining external buffer areas with light fuels (low-intensity fire at 5–6 year intervals in spring);
- regeneration of tamar thickets using moderate-intensity fire in summer or autumn at intervals of 20–25 years; and
- regeneration of leguminous shrubs (*B. ornata*, etc.) with moderate intensity fires in summer every 9–12 years to provide habitat and nitrogen inputs for woylies (Shea et al. 1981).

Further research on the behavior of high-intensity fires has been necessary to draw up prescriptions to allow safe use of such fires in summer. This has been carried out as a cooperative part of the Aquarius program.

Research into the biology of native flora and fauna and into the behavior of fires in different fuel types is required to draw up ecologically sound fire management programs in other parts of Australia.

THE 1983 EXPERIENCE

Drought conditions persisted for much of 1982 and continued on into 1983. By January a severe rainfall deficiency had existed over most of southeastern Australia for 10 months. Much of South Australia and the forest areas of Victoria had their lowest rainfall on record for the 10-month period ending January 31, 1983 (Neal 1983). In New South Wales and northern Victoria, pastures were completely eaten out, practically eliminating the danger of grass fires in these areas, but forest fuels were extremely dry from the south coast of New South Wales through to Adelaide, South Australia. There were few areas in southeastern Australia carrying reasonable pasture. One of these was in the southeast of South Australia, which normally has quite extensive areas of moist swamps in most summers.

The driest forest zone was in eastern Victoria. Three major fires of 12 000 ha, 27 000 ha, and 20 500 ha burnt during November. On January 8, 12 000 ha of forest was burnt in central Victoria and two fire fighters were killed. Up to this stage most fires had been confined to sparsely populated forest areas. Pastures in eastern Victoria were sparse and eaten out, and fire suppression in the grasslands presented few problems.

On February l more fires broke out in the forests of Victoria under strong northerly winds in association with a dry cold front. The Cann River fire in east Gippsland burnt more than 100 000 ha over 12 days, crossed into New South Wales, and burnt 5500 ha of *Pinus radiata* plantation. This was a record loss for a plantation fire in Australia with damage estimated at $12 million, a record that was to be short-lived. Another fire in Mt. Macedon, a fashionable residential area within commuting distance of Melbourne, burnt 6000 ha and 24 homes.

On February 15 an anticyclone over New Zealand extended a ridge toward central Australia, and in the Southern Ocean a cold front was advancing northeastward. The pressure gradient over eastern Australia was fairly weak and surface winds were light. This is a familiar pattern in summer and usually recurs every 7–8 days. The pressure gradient usually becomes steeper as the front approaches, bringing stronger dry northerly winds to southern Australia ahead of a cool change with south to southwesterly winds.

A deep reservoir of hot dry air existed over central Australia. This was drawn south by large pressure falls in the Great Australian Bight and a new front formed ahead of the front in the Southern Ocean. During the morning of February 16 (Ash Wednesday), this new front intensified and gale-force northerly winds carrying dust from the parched interior swept over South Australia and western Victoria, dramatically reducing visibility. The front moved across South Australia during the afternoon and winds appeared to be intensified by the approaching cold front in the Southern Ocean. Mean wind speeds of 40–50 kmh^{-1} were recorded in open locations before the change. After the change, mean winds were southwest around 70 kmh^{-1} with gusts over 110 kmh^{-1}, and these persisted for more than two hours.

In both South Australia and Victoria, fires broke out and burnt rapidly southward under the influence of the gale-force northerly winds. Suppression of the flanks was impossible, and when the wind changed to the southwest the fires broke away along the whole of the eastern flanks. In the most extreme case the fire had traveled 60 km in a southerly direction before the change.

In the Adelaide Hills seven fires burnt 38 900 ha. Again, sparse pasture limited the rates of spread in grasslands and the major spread and damage occurred in timber and scrub areas near Adelaide. Fourteen people were killed and 260 houses were destroyed or seriously damaged. In the southeast of the state pastures were light but continuous, and rates of spread of 18–20 kmh^{-1} were recorded for several hours. Here eight fires burnt over 120 000 ha, including 18 500 ha of pine plantations. Rates of spread in the plantation were up to 10 kmh^{-1}. Fourteen people were killed and 123 homes were destroyed.

In Victoria eight major fires burnt 183 000 ha on February 16 and wiped out several towns and seaside resorts. Forty-seven people perished and 2186 homes were destroyed. Estimates are that the cost of the fires may exceed $400 million.

Over the 1982–83 fire season the Forests Commission of Victoria lost 518 000 ha of native forest but only 2360 ha of pine plantations (Duncan 1983).

COMPARISON OF 1983 AND 1939

When the forest fire danger rating system was developed, the index value of 100 was based on the following combination of weather variables: drought factor 10 (maximum), temperature 45°C, relative

Table 2. Comparison of fire danger at Melbourne, January 13, 1939, and February 16, 1983

Time	January 13, 1939				February 16, 1983			
	Temp. (°C)	RH (%)	Wind (kmh-1)	FFDI (units)	Temp. (°C)	RH (%)	Wind (kmh-1)	FFDI (units)
09:00	36	20	30	42	28	20	10	20
12:00	45	8	26	78	39	8	22	89
13:00	45	8	30	87	41	7.5	19	60
14:00	45	8	36	100	42.7	7.5	30	81
15:00	44.5	8	22	70	43	5	28	86
16:00	32	20	13	25	43	5	26	81
20:45[a]					43	5	37	106

[a] Maximum FFDI associated with passage of a frontal squall.

humidity 8%, and mean wind strength 36 kmh-1. These were the maximum conditions recorded at Melbourne at 14:00 (Foley 1947) on January 13, 1939.

Wind speeds for assessing fire danger are now measured in an open location, whereas wind speed records at Melbourne are taken under conditions of considerable turbulence from surrounding obstructions. To compare the conditions in 1983 with 1939, however, it is necessary to calculate fire danger indexes from the Melbourne station (Table 2).

In 1983 winds measured in open locations (e.g., Tullamarine and Avalon airports) computed a fire danger index of 133 (temperature 43°C, RH 5%, wind 45 kmh-1) during the afternoon, and an index of 190 was computed during the frontal passage when the mean wind speed reached 70 kmh-1. Data from the same location, however, suggest the maximum fire dangers on January 13, 1939, and February 16, 1983, were very similar. In 1983 extreme conditions persisted longer (15 hours compared with 7.5 hours in 1939), and the wind strengths associated with the frontal squall are probably the highest recorded for summer conditions in Australia (Neal 1983). On the other hand, in 1939 extreme fire danger conditions occurred on 4 days in close succession (January 7, 8, 10, 13), with fire dangers probably exceeding 100 on both January 10 and 13. In contrast, in 1983 the fire danger was extreme on February 8 and winds in Victoria were generally light in the days leading up to February 16.

CONCLUSION

The fire weather conditions on February 16, 1983, were similar to those that occurred on January 13, 1939. Wind speeds recorded at Melbourne on both days underestimate the winds in open and forest areas. The maximum forest fire danger on both days exceeded an index value of 100 in many areas.

It is possible that these conditions may have a return period of 50 years, although conditions of extreme fire danger (FFDI >50) occur much more frequently. Under these extreme conditions known suppression techniques and firebreaks will fail. Fuel reduction programs can limit the spread and intensity of wildfires, but to be effective they must be applied to a significant proportion of the forest estate each year.

As the history of native flora and fauna becomes better understood, it will be possible to prescribe fire regimes that will achieve the joint aims of conserving natural values and protecting commercial timber resources from high-intensity wildfires.

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AN EXECUTIVE SUMMARY

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Good morning. First, my thanks to the 1983 Program Committee for extending the invitation for me to participate at this fire management workshop. I also congratulate the council and the organizers for planning and conducting a meeting with an impressive roster of speakers and for tackling a subject that has been long-overdue in the fire community. The wide-ranging attendance from the United States, agencies across Canada, the forest industry, and fire suppression suppliers is most impressive; I have never attended a fire conference where 225 people attended to discuss common concerns, share information, and chart direction for the future. You are to be congratulated.

I must wonder, however, why you asked a flatlander from the swamps of eastern Canada to speak to a group of fire managers that we in Ontario have traditionally looked to for innovation and new ideas. Of course, I would not miss the chance to visit the mountain country, and if you notice Kincaid and me with kinks in our necks or sunburns on the roof of our mouths, you will know the reason why.

During the past two days, we have had an opportunity to listen to informative presentations, contribute to interesting discussions, enjoy well-planned field trips and, of course, have a taste of the traditional western hospitality. It is a formidable challenge for me to summarize concisely the information and concepts that have taken place the past two days. Let me begin.

Al Jeffrey did an excellent job of introducing the theme of the conference and outlining the program. As Al pointed out, the theme of the conference, "Suppression options and alternatives", is extremely appropriate and timely in this time of government constraints, rising costs, and increasing client expectations. In the past few years, suppression expenditures have increased dramatically all around the world (Jeffrey noted a cost of $232 million in 1982 in Canada), and it is essential that we consider all suppression options and alternatives and assess the cost of these choices relative to the mandate we have as fire managers. As responsible, professional fire managers, we must concentrate and accelerate our efforts to develop and implement fire management programs that are an integral part of land and resource management, and that are ecologically, socially, and economically sound.

Al also cited the need for ingenuity, persistence, innovation, and dedication to the task of improving fire management programs. A key component of this effort must be in the international sharing of ideas, concepts, techniques, and technologies, as exemplified by this workshop. As we all know, fire control is a universal problem that knows no borders. We must continue to work together in addressing the problems we face and the solutions we develop.

The economical and social importance of forest lands in Canada, United States, and many other parts of the world are well known. The value of the remaining forest base, in terms of both economic and social measures, is rising as the competition for the remaining forest base and investments for the future increase dramatically. As the pressures mount, political considerations and involvement become more and more paramount. It is these very factors and considerations that shape and determine the range and scope of the suppression options and alternatives available to us as fire managers. It is appropriate then that the first panel group, moderated by Dick Krebill of the U.S. Forest Service, dealt with the subject of socioeconomic and political considerations.

Our ability to spend suppression dollars has reached new heights and this, coupled with the current thinking that fire is a natural force and our increased knowledge in fire sciences, makes for very exciting times. It is appropriate for us to examine our policies and to ensure that social, economic, and political considerations are understood. The nagging question remains: what is it really worth to put fires out?

Tom Mills of the Pacific Southwest Forest and Range Experiment Station pointed out to us just how complex and difficult it is to estimate the impacts of fire on the value of resource outputs. There are a wide variety of approaches possible, a large number of variables involved, numerous factors that have to be taken into consideration, and substantial difficulties encountered in assigning dollar values to many of the impacts. Regardless of the complexity and difficulty of this problem, we must continue to encourage and support efforts such as this. As competition for a share of the public purse and the costs of doing business increase, it will be even more important for fire managers to be able to demonstrate the value and economic efficiency of their programs. Tom's paper will provide one basis for us to come to grips with this concern; however, as one questioner pointed out, to be really effective the managers must understand what went into the model and the tables should be updated every 2–3 years.

Charlie Van Wagner presented a different approach to this problem that has been eluding fire researchers and managers for decades. In contrast to the approach described by Tom Mills, Charlie's concept focuses on the whole forest and its timber yield rather than the direct on-site and indirect off-site impacts. He has related it to the "least cost — plus loss" concept that fire managers have been so familiar with for many years, but suggests that because loss in this approach is now conceived as a reduction of timber supply rather than as the fire-killed timber on the burned area, the approach should be called "maximized net return". As Charlie pointed out, there are still lots of questions to be resolved with this approach. It is clearly a matter for specialists from many disciplines. As fire managers, we must orchestrate, encourage, and participate actively in these discussions. For me, Charlie's paper is a breath of fresh air as his approach is logical and workable. Perhaps we are ready to move the yardsticks on this issue.

As Charlie Van Wagner indicated in his paper, "social and environmental concerns acting through the political process may control what is done about forest fire just as much as rational economic analysis". Cliff Smith clearly identified and described some of the political implications of fire management in Alberta. More and more our actions are subject to public scrutiny, and the fire manager and the politicians are now front and center during fire flaps but all too often fade into the woodwork once the fire activity is no longer newsworthy. Cliff also gave us some future challenges, including the following concerns:

1. flat line budgets and staffing,
2. values at risk — must come to grips with it,
3. mutual aid,
4. fire prevention (insect damage), and
5. use of fire.

The afternoon session of Day 1 of the program dealt with the subject of strategy and tactics. The session was moderated effectively by Carson McDonald of the Alberta Forest Service (AFS). This session was broken down into two parts: the first part dealing with initial attack, and the second with escaped fires.

Effective initial-attack systems are key components of all fire management systems. Having sufficient resources in the right place at the right time in anticipation of the expected fire load is essential. Howard Gray and Ben Janz of the AFS provided a very concise overview of the approach Alberta is now taking. First Ben placed the problem in perspective with an overview of the geography, fuels, and weather that influence the program. Ben's work with the 500-millibar analysis was particularly interesting and I know many of us are taking Ben's ideas back with us to attempt to apply them at home. Howard Gray then provided us with a description of a planned response system developed by the AFS in an attempt to improve the effectiveness of its initial-attack system and reduce future fire losses. As Howard said, the period 1979–1982 set new records in Alberta in terms of fire incidence, fire losses, expense, and suppression resource commitments. The presuppression preparedness system provides fire managers with man-up and deployment procedures that react to daily specific forecasted fire danger ratings. The 1983 results are impressive and the bottom line is that they are cost-effective. The details provided concerning the system and Alberta's experience with the system will certainly be a guide to other agencies that have their own systems to develop or improve.

Dave Martell of the Faculty of Forestry, University of Toronto, described how operational research techniques could be used to assist fire managers in making daily initial-attack deployment decisions. Deployment decisions are complex because of the uncertain nature of the fire load to be managed and the uncertain effectiveness of the available suppression resources in dealing with this load. The wide variety of suppression resources and transport methods available to fire managers adds to this complexity. We must make use of all technology that will assist us in making better decisions in every area of fire management. In Ontario we have been working with Dave and Peter Kourtz of the Petawawa National Forestry Institute to develop and evaluate a wide variety of decision support systems to assist decision-makers at all levels of our organization. We recognize that if we are to enhance our abilities to deliver effective and efficient fire management programs, we are going to have to harness all available technology, including operational research techniques. This will involve fire managers working closely with specialists in the field such as Dave. We in fire management are certainly fortunate to have access to numerous specialists who are not only highly qualified in the field of operational research, but who also are knowledgeable about fire management and are dedicated to its improvement.

The second part of the afternoon program dealt with escaped fires. Of course, our primary efforts are aimed at preventing these fires. As we are all aware, however, despite our best efforts, fuel, weather, and fire conditions occasionally combine to produce situations that are not currently controllable. Fortunately, these fires only represent a small percentage of our total fires actioned. Unfortunately, they frequently do the most damage and cost the most to suppress. With new policies, fire management agencies do not have to attack aggressively and suppress all of these escaped fires. A variety of response options and alternatives that consider economical, ecological, and social factors are the order of the day.

Bob Bailey of Indian and Northern Affairs Canada described for us his department's methods of managing large fires in the Northwest Territories and some of the unique problems encountered. It is particularly refreshing to note the public participation they have achieved in developing their Attack and Observation zone designations.

Elmer Hurd discussed the management of large fires in Alaska and emphasized a key component of the operation: the fire management planning process. As protection requirements have been identified in greater detail and fire management policies have changed, there has been a greater need for an opportunity to develop fire activity plans for suppression and management. These plans provide the foundation upon which the rest of the program is developed. The interagency fire planning process developed in Alaska is excellent and provides a fine example for other agencies to examine. As Elmer stated, although only 50% of the fire-prone area of Alaska has been reviewed under this process, significant benefits have already been identified in terms of reduced suppression costs, better use of suppression resources, and vegetation management for wildlife. The four management options being used are most interesting: critical, full, modified, and limited.

Hank Doerksen described the management of large fires in British Columbia from a provincial perspective. In British Columbia, three suppression options are available: no action, limited action, and full action. As Hank demonstrated, the decision-making process used to select an option is not simple and involves line managers at the district, regional, and headquarters levels.

Decisions must be made quickly, but must also take into consideration a wide variety of factors. It is essential that these decisions be made by managers who have the responsibility for the consequences. The case history of the Swiss fire clearly pointed out just how important this decision-making process is in the province. Public relations aspects of large fires are now a reality and we must harness that opportunity to sell our message.

Ron Kincaid dealt with the management of large fires in my own province of Ontario. As you are aware, Ron is the fire management officer in the northwestern region of the province and was faced with managing a number of large fires in his region in early September. As Ron pointed out, Ontario does have a new fire management policy that provides fire managers with the opportunity to select suppression strategies based on economic, ecological, and social considerations. Prior to 1982, Ontario's fire exclusion policy required aggressive action on all fires. Various other initiatives are also under way to facilitate the implementation of the new policy. Area plans are being developed by interdisciplinary teams to identify and establish fire prescriptions for each resource area that specify the acceptable level of fire loss or the amount of prescribed fire required. By the spring of 1984 fire management operations in Ontario will be more centralized in nature. The command and control of all fire operations will be planned, coordinated, and directed from the regional level. Plans to guide this operation are being developed at the present time. It is anticipated that these changes will allow us to meet the demands of our clients in an effective and efficient manner for years to come.

Yesterday, the morning session dealt with a wide variety of additional perspectives, including fire management options in Canada's national parks, private sector perspectives, and the use of aerial ignition devices for indirect attack.

Nick Lopoukhine kicked off the morning session with an excellent discussion of suppression options and alternatives in Canada's national parks. Obviously, the change from fire control to fire management has not been easy for wilderness fire managers either. The technical complexity of implementing a fire management program for wilderness area management is immense. Not only do the situations created by years of fire suppression in these areas have to be resolved, but plans that will recognize fire as a renewal agent have to be developed. The Banff National Park example presented by Cliff White clearly demonstrates the issues involved. In wilderness areas, as well as in other fire management areas, suppression options must be selected and introduced carefully after thorough planning and preparation. We must ensure that we have adequate knowledge of fire behavior, fire impacts, and our suppression capability under a wide variety of conditions. Attitudes of the public and our own resource management personnel have to change. As fire managers we must be able to demonstrate that we can carry out the new policies in a safe, economical, and highly professional manner. Fire exclusion is not the only option available.

An interesting private sector perspective was presented by Mick Koppang of the Clearwater-Potlatch Timber Protective Association. We must seek and develop partnerships such as this with private groups and landowners. Responsibility for fire management must be shared with all those who have a vested interest in the forests and wildlands of our two nations. In Ontario, we are building these relationships with the forest industry through the Ontario Forest Industries Association. Approximately 100 7-man fire crews have been provided for initial attack and line-holding activities by Ontario's forest industry. They have already proven to be a valuable supplement to Ontario's existing suppression force. Other benefits associated with this shared responsibility are also expected in the area of more fire-safe operations and fewer industrial fire starts. Mick, I might add that your description of your corporation reminded me of the situation in the province of Quebec.

There are other suppression attack options in the large fire situation that are effective and less expensive. Dennis Quintillio ably demonstrated this with his paper detailing the Alberta experience with aerial ignition devices. I liked his distinction between backfiring and burn-out tactics. The system is effective and successful during peak burning periods as long as trained teams are available and backup is provided.

Finally, Phil Cheney offered a fascinating look at fire management in Australia. The four management options of let burn, total suppression, area P.B., and using a different burning regime for a total fire package are not that different from what is happening in North America.

The 1983 fire problem in southeastern Australia was particularly interesting and offered a number of lessons for all of us. Can it happen on this continent? I think we know the answer.

Let me summarize by returning to our workshop theme, "Suppression alternatives and options". It is my view from the papers and discussions that to develop and achieve suppression alternatives, you need nine things. Let me list them.

1. Policy: flexible as opposed to rigid, which allows you to tailor responses to the needs of the situation. Old fire exclusion policies were rigid and basically considered only one alternative. New policies are modern, flexible, and progressive, and can adjust to internal constraints, (e.g., resource shortages) as well as changing external factors, (e.g., values, politics).

2. Fire impact assessment systems that allow you to assess the impacts of fire and set objectives and performance measures for areas. These are key inputs to the decision process when designing and selecting options to be followed.

3. The political considerations unique to each government have a significant impact on fire management policies and program implementation. These must be accommodated by the fire management program policy and delivery people if acceptable levels of protection and funding requirements are to be compatible with overall government policy and client needs.

4. Planning systems that allow you to implement the policies and meet the objectives and measures for the areas being protected.

5. Initial-attack systems that are effective and efficient, and that can be deployed where required, when required, and in the strength required (e.g., deployment tools as in the Alberta example).

6. Large fire management systems to implement the plans and policy on those fires that will always escape despite our best efforts. Suppression options must consider economic, ecological, and social factors.

7. High level of knowledge and professional expertise to carry these programs out, whether in wilderness areas or resource production areas (e.g., fire behavior, impact, suppression effectiveness).

8. Assistance, cooperation, and involvement of all forest users especially the woods industry.

9. The application of all available technology to assist fire managers, whether in operations research or in tools such as aerial ignition.

All of these have been dealt with in detail at this workshop, and if taken in context, provide the basis for developing and selecting suppression alternatives and options.

Mr. Chairman, my congratulations to you and your group for a successful conference.

BIOGRAPHICAL SKETCHES OF SPEAKERS, MODERATORS, AND AUTHORS

BAILEY, Robert P. Head, Fire Control, Indian and Northern Affairs Canada, Fort Smith, NWT.

Obtained a diploma in Forest Technology from Lakehead University in 1971 and a B.Sc. from Lakehead in 1973. Worked with Abitibi Paper at Thunder Bay, Ontario, for a year before joining Indian and Northern Affairs in 1974 as an Assistant Resource Management Officer at Inuvik, NWT. He has worked as a District Protection Officer in Inuvik and a Training and Standards Officer in Fort Smith before assuming his present position in 1981.

BISGROVE, Gordon. Forest Protection Officer, Alberta Forest Service, Slave Lake, Alberta.

Received a Technician diploma from the Northern Alberta Institute of Technology. Worked for the Alberta Forest Service since 1963 in Peace River, Bow, Edson, Footner Lake, and Slave Lake forests. He has been a forest protection officer for 6 years.

CHENEY, N.P. (Phil). Senior Research Scientist, Fire Research Section, Commonwealth Scientific and Industrial Research Organization, Division of Forest Research, Canberra, A.C.T. (Australian Capital Territory).

Holds a B.Sc.F. from the University of Melbourne and a diploma in in forestry from the Australian National University. Worked as a fire research officer with the Forestry and Timber Bureau, Forest Research Institute, Canberra, from the early 1960s to 1975 before assuming his present position. His research work has taken him to nearly all the major regions of Australia. He is considered a recognized authority on grassland and forest fire behavior in Australia. He has had several foreign consulting assignments for FAO-UN (e.g., Turkey, Zambia) and has numerous publications to his credit. He is currently coordinator of "Project Aquarius", code name for a series of experiments to evaluate the effectiveness of large air tankers and fire retardants, the effectiveness of conventional fire fighting techniques, and a cost/benefit analysis of forest and bush fire suppression in Australia.

DOERKSEN, H.G. (Hank), C.E.T. Director, Protection Branch, Ministry of Forests, Victoria, B.C.

A graduate of the B.C. Forest Service Ranger School, Hank holds a diploma in public administration from the University of Victoria and is a certified member of the Society of Engineering Technologists. He joined the B.C. Forest Service in 1953 as a dispatcher and has been promoted through the ranks of assistant ranger, deputy ranger, forest ranger, ranger supervisor, forest protection officer to his current director's position. Currently he is responsible for the Protection Branch, which is comprised of fire management and pest management.

DUBE, Dennis E. Superintendent of Forestry, Winnipeg Parks and Recreation Department, Winnipeg, Manitoba.

Received a B.Sc. in Wildlife Technology from the University of Montana in 1966 and an M.Sc. in Botany (plant ecology) from the University of Alberta in 1976. He joined the Canadian Forestry Service in 1973 as a Fire Research Officer and from 1980 to 1984 was Project Leader, Fire Management Systems.

FLOWERS, Patrick J. Research Forester, U.S. Department of Agriculture, Forest Service, Riverside, California.

Received a B.Sc. in forest management in 1978 and an M.Sc.F. in forest economics in 1981, both from the University of Montana, Missoula. Worked as a research assistant, University of Montana, from 1980–81. In his present position with the USFS, he conducts economic research including estimation of fire-induced net value changes for timber, range, water, and recreation resources in the northern Rocky Mountains.

GOODMAN, John F. Director, Aviation and Fire Management, Ontario Ministry of Natural Resources, Sault St. Marie, Ontario.

Obtained a B.Sc.F. from the University of New Brunswick in 1964. He has worked with the Ontario Ministry of Natural Resources as a Fire Project Forester, Toronto (1964-67); Timber Forester, Thunder Bay (1967-73); Supervisor, Forest Fire Control Branch, Toronto (1973-78); Staff Assignee to Assistant Deputy Minister, Organization and General Administration (1977-78); District Manager, Sioux Lookout District (1978-81); and Director, Aviation and Fire Management, Sault Ste. Marie (1981-present). Chairman of CCREM Fire Task Force during Canadian Interagency Forest Fire Centre establishment and CL-215 National Fire Bomber fleet acquisition.

GRAY, Howard. Head of Fire Control Operations, Alberta Forest Service, Edmonton, Alberta.

Joined the Alberta Forest Service in 1964 and worked up to a District Ranger in 1971-72. In 1972, he became a district protection officer with the Northwest Lands and Forest Division of the federal government in Inuvik, NWT. He became Chief Protection Officer in 1973 in Fort Smith, NWT. Returned to the Alberta Forest Service in 1976 as Senior Officer, Planning Section, in Edmonton. In 1977, returned to a field operational role as Forest Protection Officer of the Slave Lake Forest, a position held until assuming his present position in 1981.

HURD, Elmer. Assistant State Forester, Fire Management, Alaska Department of Natural Resources, Division of Forestry, Anchorage, Alaska.

Received in-service techical fire and managerial training to the GHQ Fire Manager qualification level. Worked in fire and timber management with the U.S. Forest Service in the Ochoco, Mendocino, and Sierra national forests during 1961-68. Joined the U.S. Department of Interior in 1968 and spent three years at the Boise Interagency Fire Centre engaged in fire training. From 1971-82 served with the USDI, Bureau of Land Management, in Alaska as a Fire Management Officer (McGrath) and Chief of Fire Management for the Anchorage District before joining the Alaska State Department of Natural Resources in 1982. Has served as a member of the cadre for national fire training, Marana, Arizona, as well as in several program development workshops at the national level.

JANZ, Ben. Supervisor, Weather Section, Forest Protection Branch, Alberta Forest Service, Edmonton, Alberta.

Holds a B.Sc. degree (Manitoba), a B.Ed. (Alberta), and an M.A. (Toronto). Worked with the Atmospheric Environment Service from 1953-80 providing weather forecasting in most regions of Canada including the prairies, east coast, Newfoundland, and the Canadian arctic. In 1980, he joined the Alberta Forest Service and has been involved in a wide range of fire weather activities with a particular interest in weather as it relates to fire behavior. He has authored about a dozen publications on meteorological subjects.

JEFFREY, Allan. Director, Canadian Interagency Forest Fire Centre, Winnipeg, Manitoba.

Obtained a B.Sc. (Forestry) from the University of New Brunswick and an M.Sc. in fire science from the University of Washington. Worked as a forest ranger with the Province of Manitoba between 1960-62. Spent one year (1966-67) with Weyerhauser Canada Limited in Sault Ste. Marie. Between 1967-81, he was employed by the Province of Manitoba as a Forester, Chief of Forest Protection, Manager of Forest Protection (Dutch Elm Disease), and Director of Regional Services. From 1981 to 1982 was Superintendent of the Forestry Branch with the City of Winnipeg before accepting his present position.

KINCAID, Ronald J. Aviation and Fire Management Officer, Ontario Ministry of Natural Resources, Dryden, Ontario.

Graduate of the Ontario Forest Technical School. Worked since 1956 with the Ontario Ministry of Natural Resources as an Initial Attack Fire Boss, Kenora District (1956-64); Forest Protection Deputy, Dryden District (1965-67); Chief Ranger, Geraldton District (1968-72); Fire Control Coordinator, North Central Region, (1973-80); and Aviation and Fire Management Officer, North West Region (1981-present). Is a Project Fire Boss Level V - Ontario.

KOPPANG, Mick. Section Manager, Clearwater Potlatch Timber Protective Associntion, Orofino, Idaho.

Received a B.Sc. degree from the University of Idaho. Worked in the Kaniksu National Forest, USFS, in 1945–46 and again between 1948–49 after spending a year in Korea with the U.S. Army. Conducted forest insect surveys in the Intermountain area between 1950–53. Was self-employed for a year (1954–55) before joining Clearwater-Potlatch in 1956.

KREBILL, Richard G. Assistant Station Director, Intermountain Forest and Range Experiment Station, USDA Forest Service, Missoula, Montana.

Received a B.Sc.F. at the University of California, Berkeley, in 1958 and a Ph.D. in plant pathology at the University of Wisconsin between 1958–62 before joining the USDA Forest Service in 1962. With the Forest Service he has served as project leader for research on native conifer rust disease and on diseases of wildland shrubs at Logan, Utah; research staff in Washington, D.C., coordinating national disease research program; staff assistant to Forest Service Deputy Chief for Research in Washington, D.C.; and managing research programs at the Rocky Mountain Forest and Range Experiment Station in Tempe, Arizona, before assuming his present position in Missoula, Montana. A member of the Society of American Foresters.

LOPOUKHINE, Nikita (Nik). Ecologist, Parks Canada, Ottawa, Ontario.

Received a B.Sc. in forestry from Syracuse University and an M.Sc. in plant ecology from the University of Saskatchewan. Worked with the Forest Management Institute of the Canadian Forestry Service during 1968–74. Worked on ecological land classification (1974–81) with the Lands Directorate of Environment Canada. In 1981 he worked with Treasury Board as a program analyst before assuming his present position in 1981 with Parks Canada as Science Advisor in Plant Ecology, including coordination of national park fire policy.

MacAULEY, A.J. (Gus). Director, Forest Fire Control Branch, Department of Parks and Renewable Resources, Government of Saskatchewan, Prince Albert, Saskatchewan.

Obtained a Resource Technology diploma from the Saskatchewan Technical Institute in 1968. Hired as a field conservation officer and began work immediately as a district manager in 1968. In 1976, he transferred to the Provincial Fire Control organization to administer the new air attack program. In 1979, he transferred to the Buffalo Narrows Region and served as regional director for one year before assuming his present position in 1981.

MARTELL, David L. Associate Professor, Forest Fire Management, Faculty of Forestry, University of Toronto.

Received a B.A.Sc. (1971), an M.A.Sc. (1972), and a Ph.D. (1975) from the University of Toronto, Industrial Engineering Department. Joined the Faculty of Forestry at the U of T as a lecturer in 1974. Conducted joint research projects in cooperation with the Ontario Ministry of Natural Resources. Research interests include the application of operational research and computer technology to forest fire management.

McBRIDE, Fred. Chief, Division of Fire and Aviation Management, Department of Interior, Bureau of Land Management, Anchorage, Alaska.

Obtained a B.Sc. in forest management from the University of Montana. Has worked since 1962 with the U.S. Department of Interior, Bureau of Land Management, as a District Fire Management Officer, Lewistown, Montana (1962–68); Chief Dispatcher, Boise Interagency Fire Center (1968–72); Fire Staff Officer, Washington Office (1972–76); State Fire Management Officer, Nevada (1976–78); Chief, Branch of Fire Management, Washington Office (1978–83); and Chief, Division of Fire and Aviation Management, Alaska (1983–present).

McDONALD, Carson S. Forest Superintendent, Slave Lake Forest, Alberta Forest Service, Slave Lake, Alberta.

Obtained a B.Sc. in forestry from the University of Montana in 1963. Worked with the Alberta Forest Service as Assistant Forester at Slave Lake and Peace River (1964); Forester, Timber Management and Silviculture, Lac La Biche Forest (1965–69); Section Head, Operations Section, Forest Protection Branch, Edmonton (1968–75); Section Head, Air Administration Section, Forest Protection Branch, Edmonton (1976–77); and Forest Superintendent, Slave Lake Forest (1978–present).

MILLS, Thomas J. Supervisory Research Forester, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Riverside, California.

Received a B.Sc. (Forestry) in 1968, an M.Sc. (Forest Economics) in 1969, and a Ph.D. (Forest Economics) in 1972, all from Michigan State University. Worked since 1972 with the U.S. Forest Service as Research Forester (1972-75) on the Forest Resource and Economics Staff, Washington D.C.; Research Forester (1975-78) at the Rocky Mountain Forest and Range Experiment Station; and since 1978 in his current position. His research includes work on the refinement of long-term timber supply projection techniques, financial return analysis of silvicultural investments, and team leadership in the development of a fire economics evaluation system.

QUINTILIO, Dennis. Senior Fire Control Instructor, Alberta Energy and Natural Resources, Forest Technology School, Hinton, Alberta.

Received a B.Sc. in forestry (1967) and an M.Sc. in forestry (1972) from the University of Montana. Worked as Fire Research Officer (1967-76) and Project Leader, Fire Management Systems (1977-79), with the Canadian Forestry Service before assuming his present position in 1979.

SMITH, Cliff B. Director, Forest Protection Branch, Alberta Forest Service, Edmonton, Alberta

Obtained a B.Sc.F. at Montana State University (Missoula) in 1963. Worked briefly with the British Columbia Forest Service in site classification before joining the Alberta Forest Service in 1963 as Divisional Forester in Peace River. Worked in the Timber Management Branch and Woods Operations Branch. Was Forest Superintendent of the Grande Prairie Forest between 1974-80 before assuming his present position. Currently vice-chairman of the Canadian Committee on Forest Fire Control. Previous chairman (1981-82) of the Rocky Mountain Section of the Canadian Institute of Forestry.

VAN NEST, Terrance. Fire Behavior Officer, Alberta Forest Service, Edmonton, Alberta.

Obtained a Forest Technician diploma from the Alberta Forest Technology School. Worked with the Alberta Forest Service since 1965 as Lookoutman, Peace River Forest (1965-66); Forest Officer, Peace River and Bow-Crow forests (1966-75); Fire Control Technician, Peace River Forest (1975-82); and Fire Behavior Officer, Edmonton (1982-present). Particular interest in the development and application of new techniques in fire behavior measurement.

VAN WAGNER, Charles E. Research Scientist, Petawawa National Forestry Institute, Canadian Forestry Service, Chalk River, Ontario.

Received a B. Eng. (Chemical) from McGill University in 1946 and a B.Sc. (Forestry) from the University of Toronto in 1960. Worked in the paint and varnish industry from 1946 to 1958. Conducted research on behavior and effect of forest fire at the Petawawa National Forestry Institute from 1960 to present.

WHITE, Cliff. Park Warden, Banff National Park, Parks Canada, Banff, Alberta.

Received a B.Sc.F. from the University of Montana. Currently working toward an M.Sc. in forestry from Colorado State University. Park warden for nine years. Responsible for vegetation resources in Banff National Park. Currently developing a fire management plan to make the transition from total fire suppression to fire management as per Parks Canada's national policy.